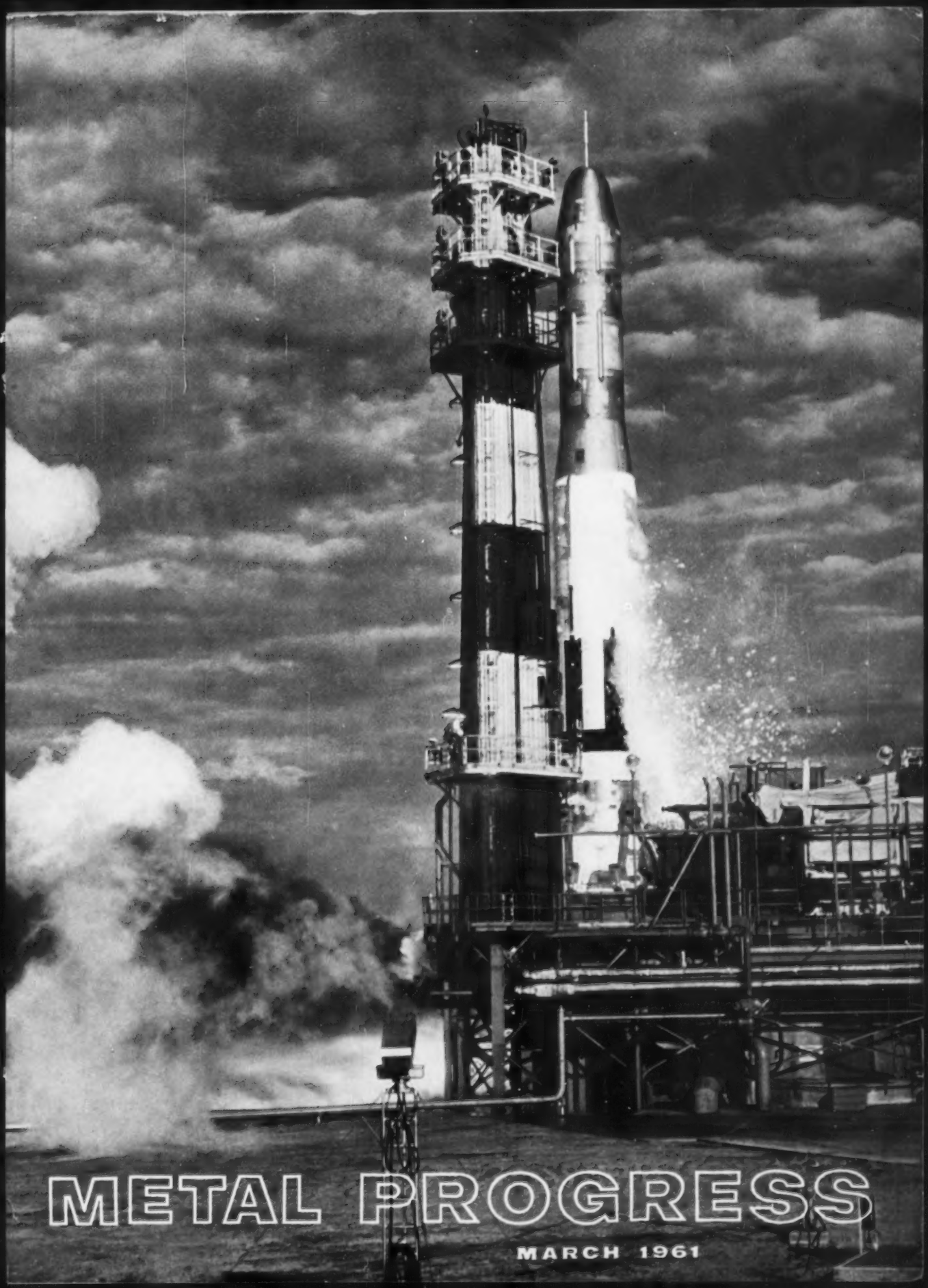


METAL PROGRESS

MARCH 1961

How Empire-Reeves gets better quality silicon steels, faster

Lee Wilson open coil annealing improves uniformity, facilitates delivery, reduces inventory at Empire-Reeves

"Improved customer service," reports Donald W. Frease, President of Empire-Reeves Steel Corporation," is just one of the assets the addition of the Lee Wilson Open Coil Annealing has given Empire."

"We can now process orders with much greater speed," he continues, "yet we can reduce our inventory in the annealing department, because—by opening the coil—hot gases can saturate the entire coil in a fraction of the time previously required. Cool-down is just as efficient.

"The quality of our silicon steels, as well as others processed through the Open Coil system, is vastly improved because the heat quickly reaches every square inch of the surface of the steel coil. This means it receives a perfectly uniform anneal with an absolute minimum of hardness variation. Because we are handling individual coils instead of continuous strip we have wonderful flexibility. We can process short orders as easily as long runs.

"The Lee Wilson Open Coil Process thus enables us to improve our customer service and our product, and at the same time, gives us the most efficient annealing system available today," Mr. Frease, concludes.

If a better product or more efficient annealing department appeals to you, why not get the last word on annealing practice. The Lee Wilson sales engineer in your area will be happy to meet with you at your convenience.

Donald W. Frease, President of Empire-Reeves Steel Corporation (center), tells J. L. Whitten, Vice President of Sales of Lee Wilson (right), and E. G. Fenton of Empire, the results of Open Coil Annealing at Empire after the first few months of operation.

Overall view of the Lee Wilson Open Coil Annealing installation at Empire-Reeves' Mansfield, Ohio, plant.

Circle 1138 on Page 48-B

Metal Progress

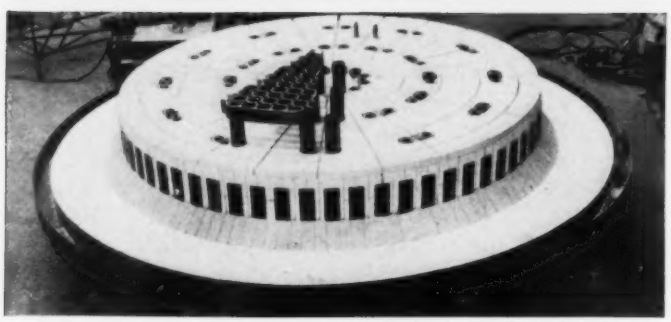
March 1961 . . . Volume 79, No. 3

COVER: The striking photograph of the Air Force Titan ICBM illustrates the theme of this March issue – Producing for the New Technologies. The 110-ton Titan (shown on the launching pad before its first guided test flight from Cape Canaveral) is steered by a guidance system produced by Western Electric Co., which provided the photo.

Table of Contents Continued on Page 3

**The coding symbols refer to the ASM-SLA Metallurgical Literature Classification, International (Second) Edition, 1958*

New Alloy Supertherm* proves itself in 2300 degree fahrenheit brazing furnace



Supertherm hearth grid segment during furnace construction.

In a brazing furnace for the thrust chambers of rocket engines at Rocketdyne Division of North American Aviation, Inc., Canoga Park, Cal., a Supertherm furnace hearth grid assembly is operating at a temperature of 2300° F. The grid in a furnace built by the General Electric Company's Industrial Heating Department at Shelbyville, Ind., supports the engine parts during a brazing cycle of from five to eight hours with a maximum temperature of 2300° F. At this extreme temperature and under severe conditions of thermal fatigue created by the brazing cycle, *the Supertherm grid has performed successfully over one year.*

Supertherm is Electro-Alloys' new alloy for the 1800 to 2300 degree fahrenheit range. The composition of Supertherm is 26% chromium, 35% nickel, and is strengthened and stabilized with cobalt and tungsten. For technical information about the composition, physical and high temperature properties of Supertherm, fill out and return the coupon or contact your local Electro-Alloys representative.

*Supertherm is a patented alloy.

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Company_____

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AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION • Elyria, Ohio

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Metal Progress

Metal Progress is published monthly by the American Society for Metals. Publication office Mt. Morris, Ill. Editorial and general offices Metals Park, Novelty, Ohio. Second-class postage paid at Mt. Morris, Ill. and at additional mailing offices. Vol. 79, No. 3, March, 1961.

By the drumful, shovelful, scoopful, handful, or spoonful . . . Sherritt nickel is about the most convenient alloying metal you can buy. No wrestling with unwieldy plates. No cutting or hacking. High-purity Sherritt nickel comes to you in handy briquettes and in three grades of powder for faster, easier alloying. These powders and briquettes go into solution more rapidly with less chilling. You can make alloying additions at the end of the heat. Special nickel grades and coated powders are also available.

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SHERRITT GORDON MINES LIMITED

Circle 1215 on Page 48-B

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PRESS BREAKS

THOSE WHO HAVE REASON to look at *Metal Progress*' "masthead" (the column appearing monthly as p. 7) will note that this month for the first time the name of

MARJORIE R. HYSLOP, *Managing Editor*

is missing. This is because she is now devoting all of her time to other duties. For 17 years – since its beginning – she has been editing *Review of Metal Literature*, and is probably the only one alive who has read *every* one of the 175,000 annotations which have been printed since then. The annual chore of indexing this material adequately enough to be useful made her an enthusiastic supporter of A.S.M.'s research project at Western Reserve University, started in 1955, to devise and test electronic methods for searching metallurgical literature. This project has been completely successful, and her new job, "Manager of Documentation Service", will require all her available time and energy to supervise the digesting operations, the encoding of the information on magnetic tape, the analysis of customer's questions in terms the machine can understand, and the sale and promotion of the service to customers scattered world-wide.

Marjorie Rud was waiting in Cleveland in mid-summer 1930 when the editor of *Metal Progress* arrived, and helped him get out the first issue that September. For 15 years she not only acted as secretary to *Metal Progress*' editor but also did much of the editorial work on *Metals Review*. (MR meaning Marjorie Rud and MR meaning *Metals Review* sometimes got mixed up, but they meant much the same thing. Then she took a new title, Mrs. John A. Hyslop.) In the mid 1940's the increasing work on *Review of Metal Literature* and a belated expansion of the editorial and clerical staff on *Metal Progress* warranted her dropping *Metals Review* and assuming such activities on *Metal Progress* as is indicated by the title "managing editor" – this in addition to the growing work on *Review of Metal Literature*. As mentioned above, in the future her work will be concentrated on documentation, but the doors to her office lead to those of her old associates on *Metal Progress*, and they are still open.

Another thing should be mentioned: She was secretary (and spark plug) of a committee of experts which devised and keeps up-to-date the Metallurgical Literature Classification of the American Society for Metals and the Special Libraries Assoc. – widely, even internationally, used.

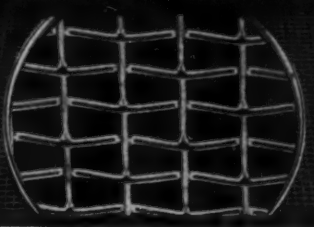
We all were worried that we would lose her when A.S.M. moved its offices 'way out in the country east of Cleveland, for John and Marjorie Hyslop were life-long residents of Lakewood, to the west, and were power-boat enthusiasts. Metals Park is about 25 miles from the nearest harbor on Lake Erie. However, they bought a charming old farm house on Lake Lucerne, about five miles from the office, spent a small fortune in modernizing its kitchen, and get their exercise trimming the greenery and paddling a canoe.

Those who have noted Marjorie Hyslop's absence from this month's masthead probably have wondered about several other changes on p. 7. April Press Breaks will have more about our revised masthead.

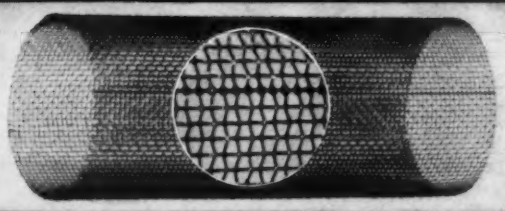
THE EDITORS

Need Wire Cloth Specials? Call *Cambridge*

BRAZED

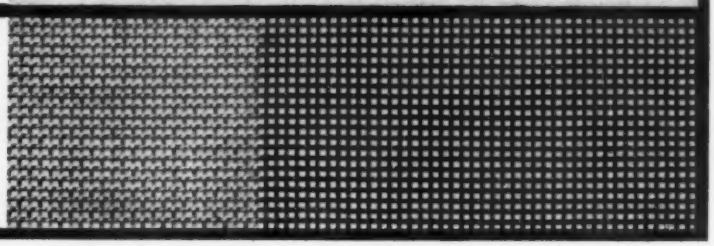


SEAMLESS



TEFLON* COATED

Right Side Coated



*Reg. T. M. of DuPont Company

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Portable "service center"

Hundreds of companies have saved money, improved products and cut production waste as the result of opportunities presented by the Ryerson "Metalogikit."

How? This unique kit is a veritable portable service center... lets you explore many alternatives to material you now use. For example, you can compare several different cutting methods on the same piece of steel to see which is best for your application.

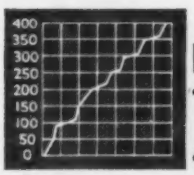
Following are a few random examples showing how Ryerson specialists, using the Metalogikit, have helped customers with a variety of problems—many similar to those you may face every day.

If you would like to put the Ryerson Metalogikit to work for you, call your Ryerson representative for a demonstration—for unbiased recommendations on steel, aluminum, plastics and metalworking machinery.

sparks new ideas and savings

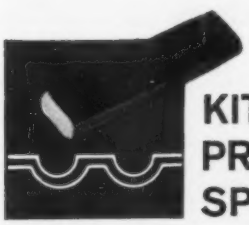
KIT SPOTS SAVINGS

Scratches and grooves normal to cold drawn, seamless tubing caused high manufacturing costs for a company making small, light-wall hydraulic cylinders. The small I.D. had to be honed to eliminate these faults—often too much metal was removed for proper piston fit. A Ryerson specialist suggested a switch to *welded tubing*. Using a sample from his Metalogikit, he pointed out the better finish that eliminates expensive honing. The switch was made with these results: higher production, low reject rate, improved product—plus lower purchase price per foot of tubing.



METALOGIKIT TURNS UP 400% PROFIT

Bidding on a routine job was delayed for one steel fabricator because of an unusual material requirement in the specs—calling for an insulating block of phenolic laminate. For help, the company turned to its Ryerson representative, who showed a sample of Ryertex® sheet stock from his Metalogikit. In addition to having the material available from stock, he was able to show how easily it could be fabricated. This Ryerson know-how, demonstrated by the Metalogikit, enabled the customer to enter his bid on time. He got the job, and made a 400% profit.



KIT SUGGESTS PROFITABLE SPEC CHANGE

Fractures and rejects were extremely high for a manufacturer cold forming two severe bends in flat, hot rolled bars. A Ryerson specialist examined the ⅜″ x 2″ bar stock and compared it with a sample of M-1020 flattened round bar from his Metalogikit. He explained how controlled carbon of Ryerson M-1020 bar would produce great cost-saving advantages in this operation over hot rolled, mild steel. After specs were changed to this Ryerson-supplied bar, fractures and rejects were substantially reduced—resulting in new profitability.

STAINLESS FROM KIT LEADS TO SAVINGS

This company had an emergency requirement for stainless sheets. Application had always called for Type 304, 16 ga. x 66″ x 81″, *polished on one side*. Their Ryerson specialist questioned the need for polishing. From his Metalogikit, he showed them a sample of 304 with a 2B finish. The company readily agreed it was exactly the finish needed *without polishing*—saving delivery time and material cost. The Ryerson man further suggested 16 ga. x 72″ x 144″, using the cut-off pieces for another job—reducing scrap waste on *both* requirements. Order was placed and delivered in plenty of time. Over-all result: a substantial saving.

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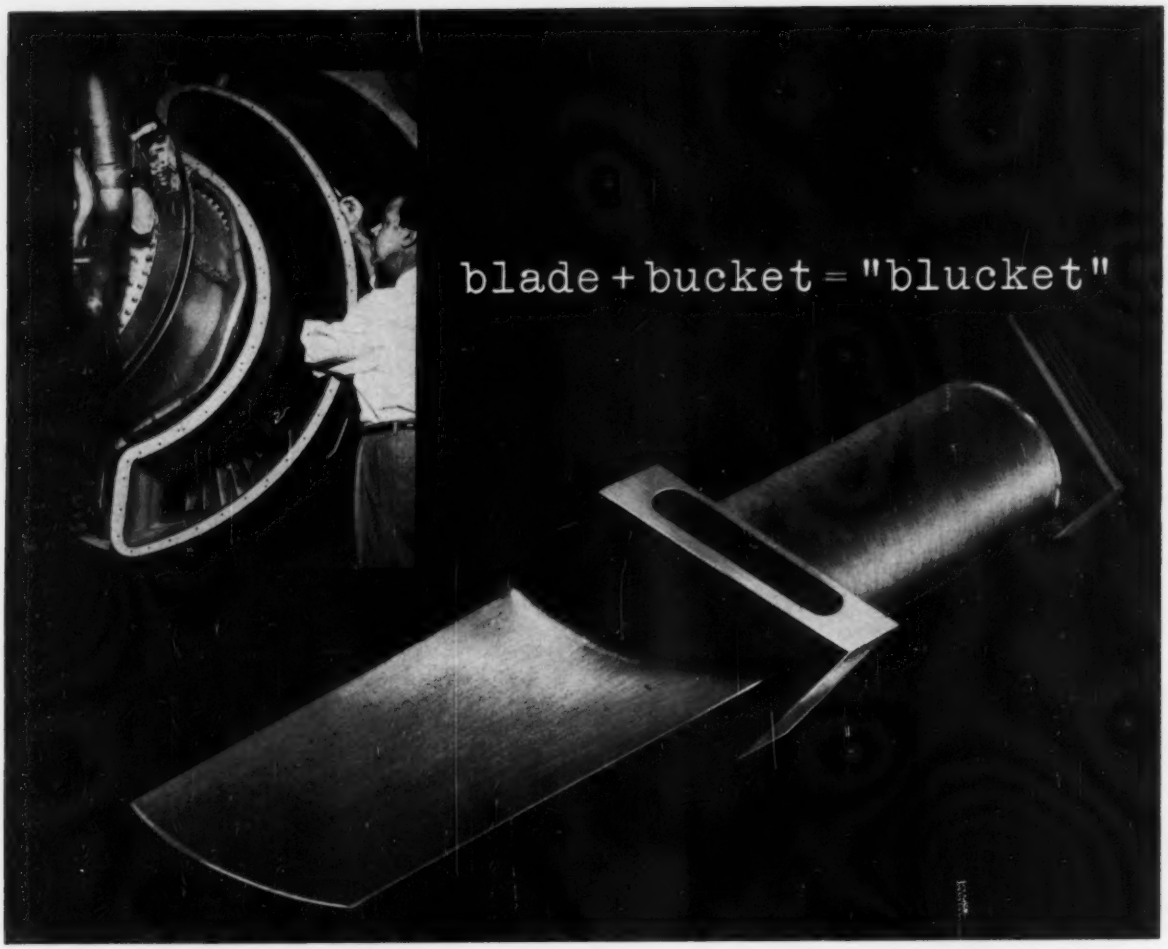

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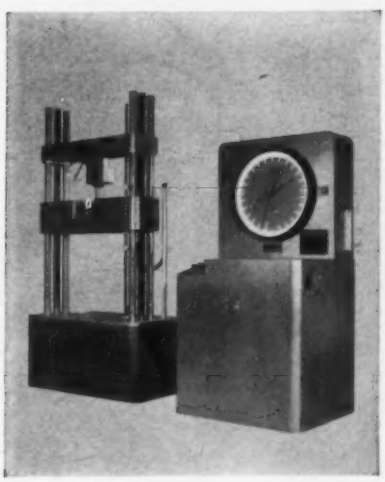

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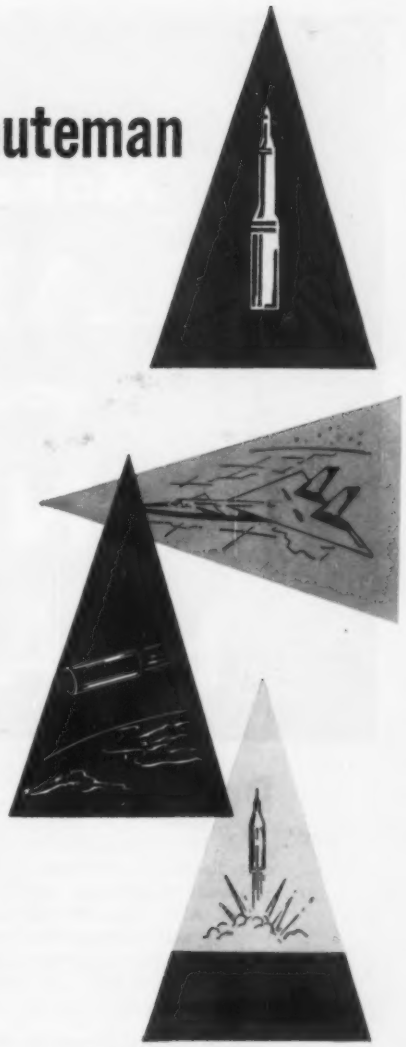

Hand in hand with many of the country's leading manufacturers of aerospace vehicles, Lindberg has expanded with the defense needs of America in the missile and rocket era. With a 39-year-background as specialists in heat treating, the men of Lindberg have unique experience and skills that add to any team effort in the solving of aerospace problems. These techniques are witnessed, too, in the active part Lindberg has played in rocket motor case treatment, right from Explorer through Minuteman.

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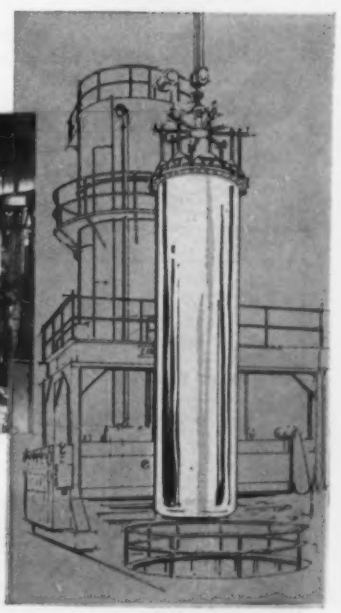

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Circle 1223 on Page 48-B

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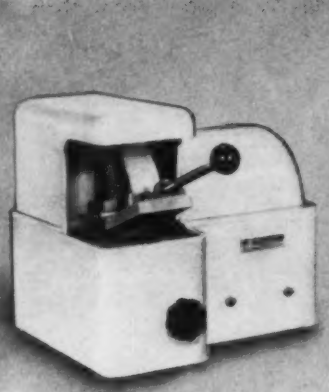
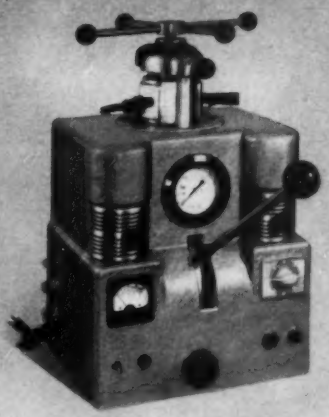
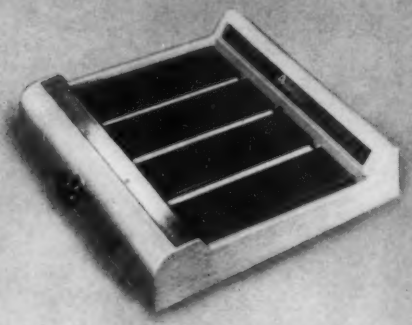


1114 AB Cutter



1330 AB Speed Press



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1500 AB Standard Polisher

1905-2 AB Automet Attachment

1720 AB Electro-Polisher

Buehler Ltd.

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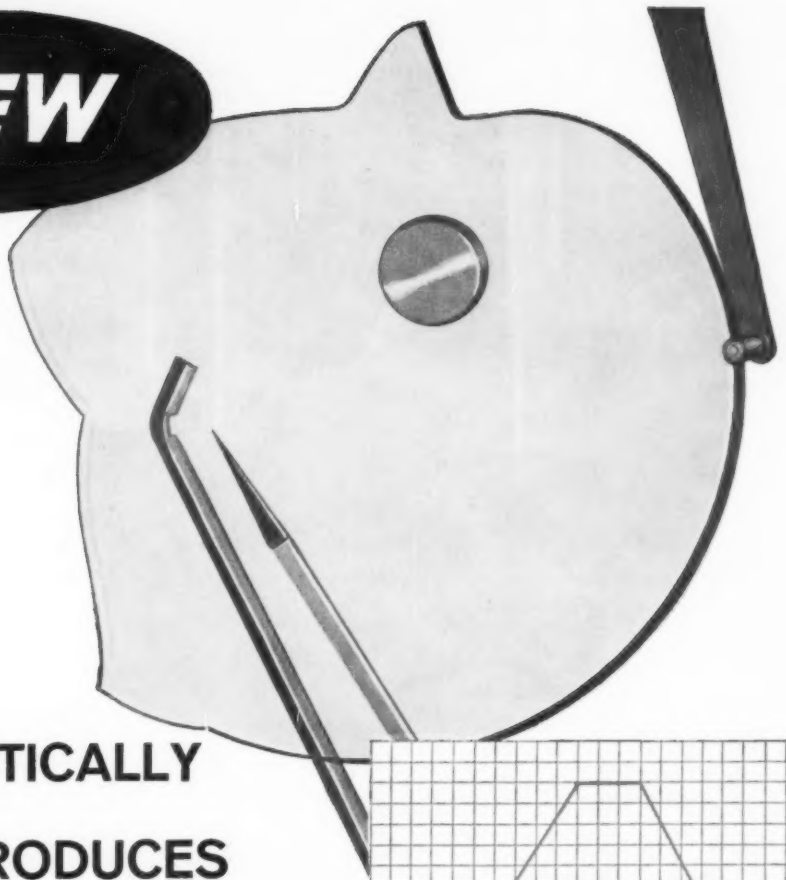
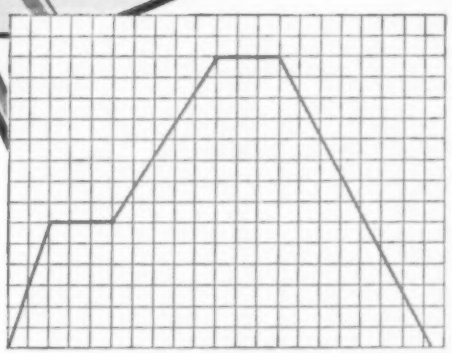
NEW

. . . through research by Barber-Colman

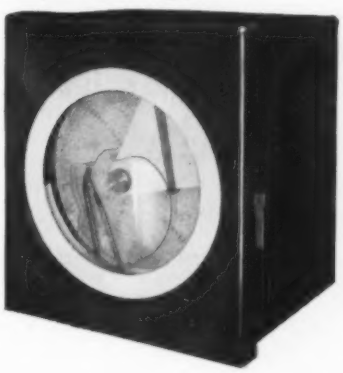


IDENTICALLY REPRODUCES PROGRAMS WITH THE FAMED "ELECTRONIC LINK"



Typical program includes 2 rise, 2 soak, and a cooling period.

The Series 2000 Cam-Operated Program Controller raises new standards in quality control. The metalworking, ceramic, and glass industries can now process batch after batch and get precise reproduction of time and temperature cycles. Wheelco's "Electronic Link" transmits cam contour to an electronic null-balance controller. Cams are easily and accurately cut in the field! Write for Bulletin F-10191 or call Barber-Colman.



BARBER COLMAN

BARBER-COLMAN COMPANY

Wheelco Industrial Instruments Division

Dept. C, 1518 Rock Street, Rockford, Illinois, U.S.A.

BARBER-COLMAN of CANADA, Ltd., Dept. C, Toronto & Montreal • Export Agent: Ad. Auriema, Inc., N.Y.

Circle 1226 on Page 48-B

This mark tells you a product is made of modern, dependable Steel.

New top for the Shippingport reactor

By the Ohio River at Shippingport, Pa., the United States' first full-scale central station atomic power plant devoted exclusively to civilian needs continues to generate electricity for the Pittsburgh district. In operation since 1957, Shippingport's reactor core received its second "seed" fuel early in 1960. The pioneer atomic plant is a joint project of the Duquesne Light Company and the Atomic Energy Commission.

The nuclear portion of Shippingport was designed and developed by Westinghouse under the direction of and in technical cooperation with the Naval Reactors Branch of the Atomic Energy Commission. The work was done at the Bettis Atomic Power Laboratory which Westinghouse operates for the AEC.

U. S. Steel's Homestead Plant supplied the forgings for the closure-head assembly needed to accommodate a new and higher power core developed by the Bettis Laboratory for Shippingport. As furnished, the 3-piece assembly weighs 81 tons—and every ounce of these USS Quality Forgings was cast, forged, machined and tested to meet the most rigid specifications.

The reactor's new closure-head assembly for Core 2 consists of a dome, torus, and head flange. The largest piece—the head flange—weighs 41 tons. To insure the highest degree of quality from the start, it was electric-furnace melted from a Ni-Cr-Mo alloy steel, then teemed into a 180-ton ingot in U. S. Steel's vacuum-casting facilities. After top and bottom discard, it was forged to an 85″ octagon; then it was upset to 60″ in height. Next a 30″ hole was punched in it to provide for mandrel forging. This hole was later opened up to take a 36″, and finally a 54″ forging bar. At this point the ring was flattened to 43″, the bar was again inserted in the center and the ring was mandrel-forged to its final dimensions—159″ overall diameter, 98″ interior diameter, and 42½″ high, as shown in the big picture. It then weighed 83½ tons and was ready for heat treating and preliminary machining. Final machining reduced the flange's shipping weight to 41 tons.

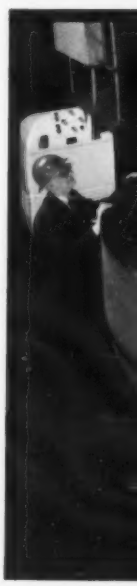
The torus, or "transition ring," was manufactured from the same grade of steel in the same careful, expert manner. It weighs 23 tons after final machining.

The dome is hollowed out on the inside and has a relatively small hole through its middle. This hole provides a refueling port; separate openings for control rod mechanisms were bored later. The dome was machined on our 20′ vertical boring mill with the aid of an electronic contouring machine. Final weight of the dome: 17 tons.

Dome, torus and flange were painstakingly tested and inspected every step of the way. Tests included ultrasonic inspection, tangential tension tests, Charpy V notch impact tests, grain size tests, bend tests and magnetic particle inspection.

U. S. Steel has the capacity, the men, and the equipment to manufacture quality forgings like these, whether they be rings, flanges, domes, pressurizers, tube sheets or other such nuclear and power plant components. And the very same men and equipment will be working on *your* order. For a free folder on USS Nuclear Forgings, write United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

USS is a registered trademark



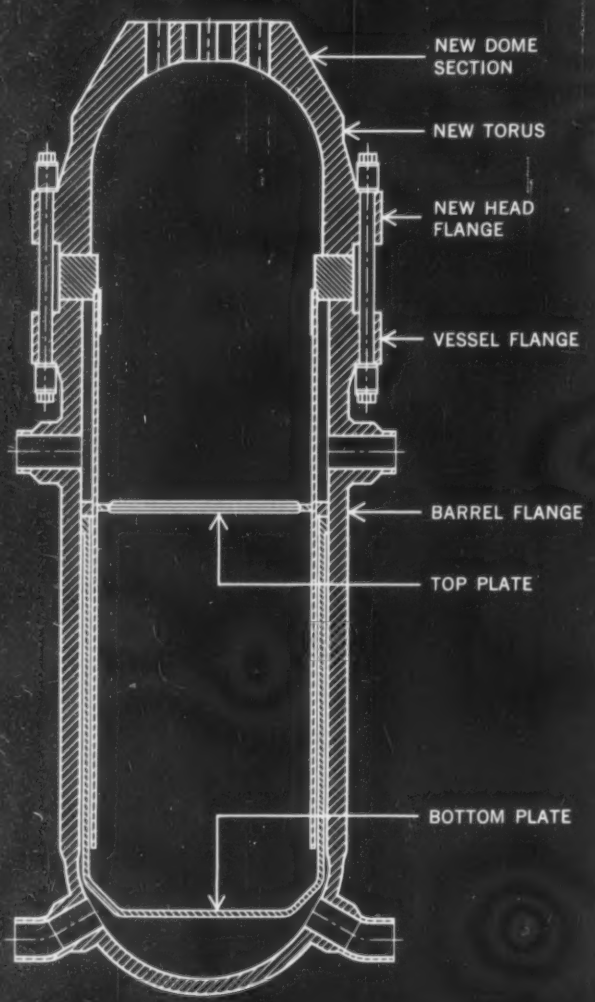
United States Steel Corporation—Pittsburgh
Columbia-Geneva Steel—San Francisco
Tennessee Coal & Iron—Fairfield, Alabama
United States Steel Export Company

United States Steel

Photos, top to bottom—
head flange about to be quenched;
torus being contour machined;
ultrasonic inspection of dome.

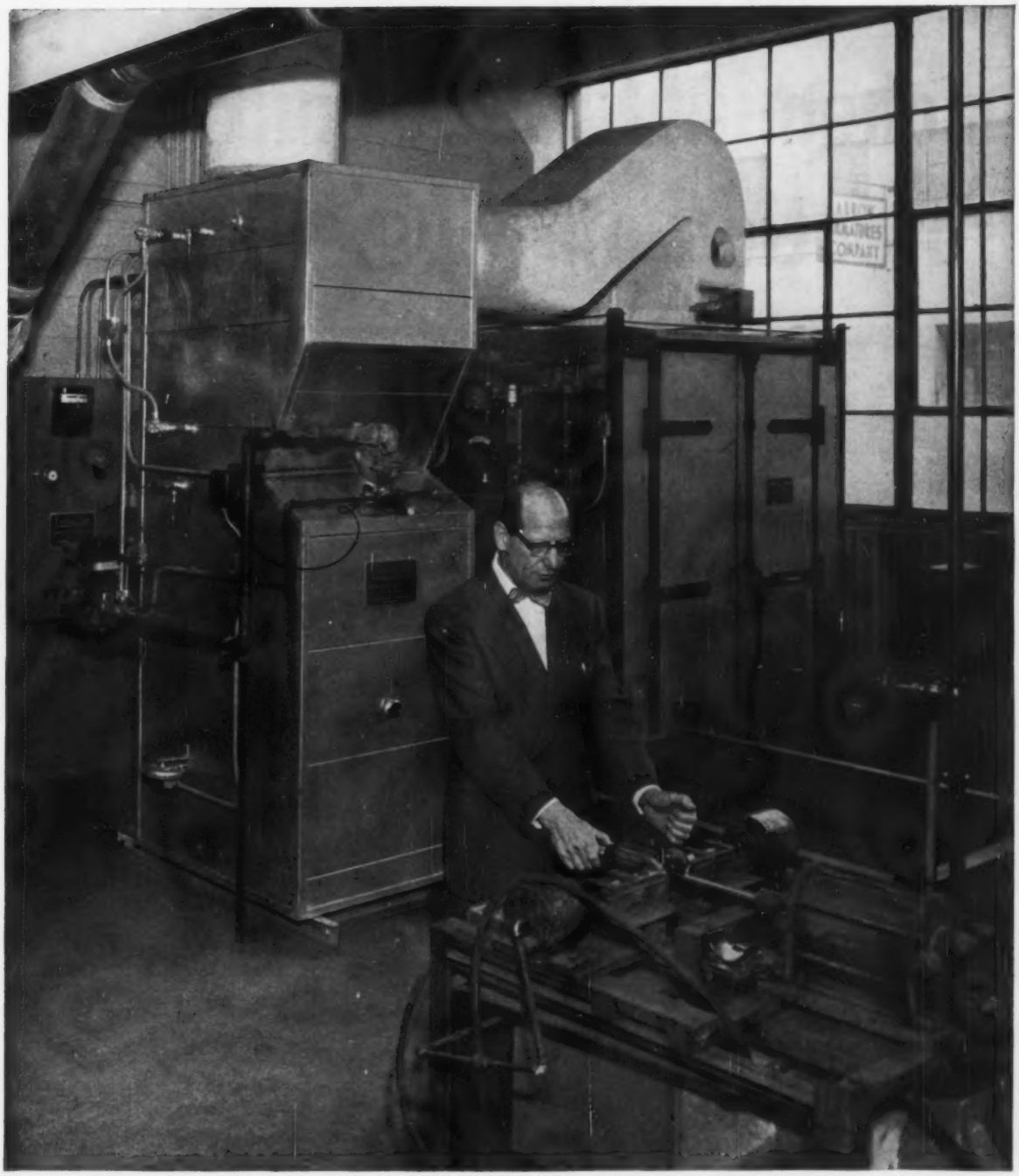
Core 2

FORGED COMPONENTS



Since the three parts of this reactor vessel head—dome, torus and flange—will be welded into a single unit, there can be no allowance for failure. Every square inch of these three USS Quality Forgings were painstakingly manufactured and carefully inspected during and after the manufacturing process to assure perfection. The men, the forging facilities and the inspection equipment are available to you if you need forgings that must be as close to perfection as we can make them.

Circle 1227 on Page 48-B



"Only GAS gives quick, controlled, complete combustion"

Albert Holzwasser, President, Arrow Armatures, Boston

"Arrow Armatures is the largest rebuilder of automobile generators in the East. One of the important steps in rebuilding generators is burning the old insulation from the armature before it is rewound. Because gas gives quick heat that can be accurately controlled, it answers our need perfectly.

"We also have a gas-fired catalytic combustion unit to incinerate the smoke and fumes produced in burning off this insulation. Together these units give us complete, clean combustion with no smoke control problems," states Albert Holzwasser, President.

Quick, controlled, complete combustion—and the many other advantages of gas—can be yours, too. For technical information, see your Gas Company's Industrial Sales Engineer. He can show you the economies and results you'll get with modern industrial gas equipment. *American Gas Association.*

FOR PRECISE CONTROL, GAS IS GOOD BUSINESS!

Circle 1187 on Page 48-B

to Insure Paint Bonding Aluminum Parts

Pioneering the commercial aircraft field since 1928, Piper Aircraft has compiled an amazing production record—*over 50,000 planes* produced during that time!

Amchem's Alodine record at Piper's Lockhaven, Pa. plant is equally amazing—since 1948, the aluminum parts on 22,000 Piper craft have been treated with Alodine for corrosion protection and outstanding paint bonding insurance!

Utilizing a straight-line, 7-stage dip Alodine tank system, Piper production experts turn out pre-paint protected aluminum parts ranging in size from 3/8-inch rivets to 10½-foot aft section skins. Piper officials, alert to the fact that aircraft are sold on looks as well as performance, back up the 12-year record of Alodine with quotes like these—

"My proof that we have a better finish is the fact that we don't have customer complaints from the field. We attribute it to the Alodine process which gives us the good paint bond we need." (Richard Gehret, Finishing Superintendent)

"Alodine is contributing to higher Piper quality, higher customer satisfaction, reduced complaints because the customer expects and gets a quality finish." (Findley Estlick, General Superintendent)

Piper uses over one million pounds of aluminum annually, fabricates ten to twelve thousand distinct and different aluminum parts . . . each and every one Alodized with Alodine to provide 1) unequaled corrosion protection, 2) excellent paint adhesion, 3) valuable ammunition that helps sell Piper's quality products the world over.

If you make any product with aluminum—there is a use for Alodine, the superior pre-paint conversion coating chemical!

*Amchem's registered trademark for its aluminum chemical conversion coating.

Al Sharp, Methods Engineer in finishing division, checks Piper exposure test racks where paint adhesion efficiency is carefully evaluated under severe environmental conditions.

Heart of the 7-stage dip Alodine system. Aluminum parts are stacked in rack-hung baskets suspended from monorail over the first three stages of the Alodine line.

The "grand old man of aviation," President W. T. Piper, poses on the flight line alongside one of the latest models bearing his name—the Piper "Aztec," last word in luxury flying.

AMCHEM **ALODINE**

Write for Booklet 1424C, contains detailed information on Alodine, plus handy Selection Chart.

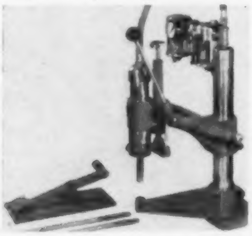
Amchem is a registered trademark of
AMCHEM PRODUCTS, INC. (Formerly American Chemical Paint Co.)
AMBLER, PA. • St. Joseph, Mo. • Niles, Calif. • Detroit, Mich. • Windsor, Ont.

Circle 1188 on Page 48-B

NEW PRODUCTS

Tool Materials, Cutting and Forming Equipment

Repeating Air Hammer



The *Heidrick-Nourse Co.* is demonstrating a bench-mounted, repeating air hammer at the A.S.M. Western Metal Show. Contact pressure of the tool on the work actuates the machine at rates varying from 3000 to 5000 strokes per min., depending on air pressure. Action varies from gentle vibration to a riveting capacity of ⅛ in. in mild steel. The unit can also be used for shaping sheet metal, inserting bushings, and for parts assembly.

For further information circle No. 926 on literature request card, p. 48B

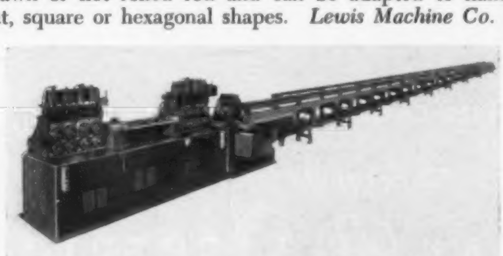
Bearing Steels

A new family of bearing steels offers higher hot hardness and improved resistance to wear, corrosion, and oxidation compared to Type 440C stainless steel. "BG41", used in high-temperature bearings and structural components, is basically 440C with 4% Mo replacing 2% of the Cr. "BG42" and "BG43" are basically the BG41 alloy with 1% and 2% added vanadium. Oil quenching, cold treating at −100° F., and double tempering at 1000° F. develops a hardness of Rockwell C-62 to 64. *Latrobe Steel Co.*

For further information circle No. 927 on literature request card, p. 48B

Straightening and Cutting Machine

The "Model 12FA" is designed to handle coiled rod up to 1 in. in diameter. The machine, powered by a 125-hp. motor, features crank action, high-speed flying shears, a two-speed rotary straightener arbor, and eight feed speeds of 115 to 350 fpm. The unit will process cold drawn or hot rolled rod and can be adapted to handle flat, square or hexagonal shapes. *Lewis Machine Co.*



Circle No. 928 on request card, p. 48B

Industrial Heating Equipment

Environmental Test Chamber

This 3 cu.ft. unit provides temperatures from −100 to +500° F. (±2° F.) as well as variations in humidity and simulated altitude. A 100,000 ft. "altitude" is attained in 30 min. (150,000 in 60 min.). Humidity ranges from 20 to 95% (±5%) at temperatures between 35 and 200° F. Thermal capacity is 1200 Btu. per hr. at −100° F. The illuminated chamber is equipped with pressurized amphenol fittings and adjustable shelves and has a 12 by 12 in. frost-free door designed to withstand thermal shock and altitude testing. *Cincinnati Sub Zero Products.*

For further information circle No. 929 on literature request card, p. 48B

Furnace Atmosphere Analyzer

A chromatographic instrument made by *Perkin-Elmer Corp.* provides accurate percentage readings of four atmosphere components – CO, CO_2, CH_4, and N_2. In gas carburizing furnaces, the system can automatically analyze and control the atmosphere so that work is held within 0.04% of desired carbon. The analyzer can be applied to routine heat treating, carbon restoration and sintering, or to openhearth and blast-furnace operations.

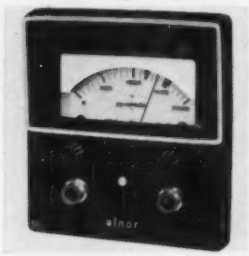
For further information circle No. 930 on literature request card, p. 48B

Heat-Processing Equipment

A wide-range furnace made by *Sunbeam Equipment Corp.* can be used for practically all heat treating operations, including annealing, hardening, normalizing, preheating, pack carburizing, stress-relieving and tempering. A 95% turndown ratio on the burners assures accurate temperature control for both ferrous and nonferrous heat processing. Gas-fired models are available in three sizes with work areas ranging from 4 in. high by 8 in. wide by 12 in. deep to 9 in. high by 15 in. wide by 24 in. deep.

For further information circle No. 931 on literature request card, p. 48B

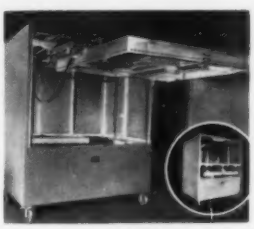
Double-Target Controller



The "N15 Pyrotroller", a temperature indicating-controlling pyrometer, provides a second contact point for secondary action. For example, in addition to controlling temperature the unit can independently actuate a valve or motor. The controller is available in eleven ranges from 0-400° F. to 0-3000° F., as well as an environmental test chamber range of − 100 to + 300° F. *The Alnor Instrument Co.*

For further information circle No. 932 on literature request card, p. 48B

Portable Radiant Heater



This heater raises metal blanks to forming temperature at the drop hammer or press, eliminating rejects resulting from loss of ductility through heat loss. A retractable lamp-head, holding 99 infrared bulbs, can generate temperatures in the work up to 1500° F. Operated by remote cable controls, the lamp-head can be raised, lowered, extended or retracted over the work, producing very rapid heating rates. *Electric Hotpack Co., Inc.*

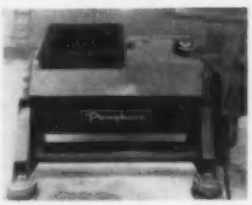
For further information circle No. 933 on literature request card, p. 48B

Etching Copper Circuits

"Resist-Etch" permits electroplating of accurately defined, detailed patterns in printed circuits – for example, lines 0.005 in. wide, spaced 0.005 in. apart. This nontoxic photo-resist material will not contaminate other plating solutions and will not produce pinholes. The product is unaffected by plating cycles, yet it is easily removed by a companion product called "Resistrip". *Sel-Rex Corp.*

For further information circle No. 935 on literature request card, p. 48B

Vibratory Finishing Machine



Designed as a production unit for finishing small parts, this machine can process a wide variety of metal, plastic, and ceramic items. The 1½ cu.ft. work container, rubber-lined, holds up to 500 lb. of material. Vibration amplitude is adjustable, and frequency can be varied while the machine is running. Air-cushioned floor mounts allow operation of the unit in buildings where spring-mounted machines are prohibited. *Pangborn Corp.*

For further information circle No. 936

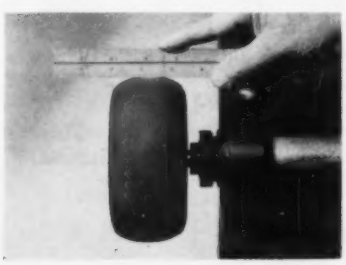
Rust Preventative

"Rust Veto 342" is a transparent protective film which is easily removed with solvent or mild alkaline cleaners. Designed to protect metal surfaces stored outdoors for long periods, this plastic coating also protects against salt

Cleaning and Finishing

Contour Grinding

When run on inflatable rubber drums, coated abrasive bands and belts assume any desired degree of crown (photo). This eliminates edge cutting which can occur when flat bands are used for contour grinding or polishing. X-weight cloth bands



contain Al_2O_3 abrasive in grits 40 through 180, bonded with all-resin adhesive. Since the degree of crown depends on grit size, drum pressure and speed, and pressure exerted on the work, these bands cannot take an exact shape. *Behr-Manning Co.*

For further information circle No. 934 on literature request card, p. 48B

A "RESULTS GUARANTEED" HEAT TREAT TECHNIQUE EVERY TIME!

The Hayes Laboratory places full-scale *production* furnaces, atmosphere generators, and allied equipment at your disposal — without cost or obligation — for developing heat treat procedures that will give the exact results your work requires. At Hayes you take an active part in process and equipment evaluation . . . you see the actual results of customized methods designed to answer your particular problem, whether it involves high-speed hardening, specialty sintering, vacuum processing, low-cost production of dry instrument air or protective atmospheres, or a hundred other processes. Most important, the equipment Hayes supplies for your job duplicates the performance of the process already proven in our lab — the results are *guaranteed!*

On Your Production Line . . . a Hayes engineer provides free start-up service to assure exact duplication of lab results . . . and to maximize benefits from equipment and techniques right from the start. He also instructs your staff on how to make your heat treating operations most economical, and how to maintain equipment for optimum output. Remember, too, that Hayes maintains a large inventory of stock parts available to help keep your equipment in top working order.

Fast, Follow-Up Service! In an emergency, our private plane will fly a Service Engineer to your plant . . . or will pick you up at any Eastern airport within a reasonable distance from our plant, and speed you to Hayes — the home of profitable, "Results Guaranteed" heat treat techniques!

How do we operate? Bulletin 1961 tells the story of the Hayes Lab. For your copy, write **C. I. Hayes, Inc. 802 Wellington Ave., Cranston 10, Rhode Island.**

C. I. HAYES, INC. SERVES INDUSTRY IN MANY WAYS . . .

Established 1905

Complete lines of controlled atmosphere electric furnaces and gas generators • induction generators • gas and liquid dryers and separators for metallurgical, electronic, chemical and petro-chemical applications • crystal growing, zone leveling, "doping", alloying and diffusion furnaces • power amplifier controls • batch type and continuous "cold wall" vacuum furnaces . . . in fact —

It pays to see Hayes whenever applying controlled heat or power to materials!

spray in overseas shipments. The film is not brittle and will not chip, crack, or flow when exposed to temperatures from −40 to +175° F. *Houghton & Co.*

For further information circle No. 937 on literature request card, p. 48B

Welding and Joining Equipment

Ultrasonic Micro-Joining

This ultrasonic kit can weld gold wires as fine as 0.0004 in. or join 0.0015 in. gold-gallium alloy sheet. It consists of a transducer handpiece and basic inserts for tweezer welding or spot welding. Any generator suitable for ultrasonic applications will drive the transducer. Micro-soldering without flux is also possible with a special heating transformer and soldering iron. Ultrasonic cavitation removes oxide film which normally interferes with fluxless soldering. *Cavitron Corp.*

For further information circle No. 938 on literature request card, p. 48B

All-Purpose Welder

Hobart Bros. Co. announces an a-c./d-c. welding machine which can be used for manual, automatic, TIG, MIG or inert-gas spot welding. The unit features automatic high-frequency control, power factor correction, and controls which permit welding with as little as one ampere of current. The "Model ADI-2641" operates from a single-

phase 230/460 power source and is rated 1 to 300 amp. (a.-c.) or 1 to 350 amp. (d.-c.).

For further information circle No. 939 on literature request card, p. 48B

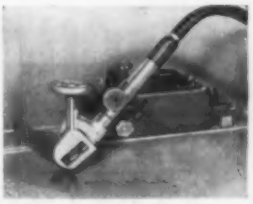
High-Temperature Brazing

Simple to operate, a torch made by *Coast Metals, Inc.* is used for high-temperature brazing and overlay work. An aspirator feeds powdered metal from a small hop-

per on the torch body into the oxyacetylene flame. For volume work, a hose connection permits drawing powder from a separate, larger container. Rate of powder flow can be easily and accurately controlled. Alloy powders are available for a wide range of applications, including hardfacing and brazing of stainless, copper, tungsten and molybdenum.

For further information circle No. 940 on literature request card, p. 48B

Automatic-Travel Torch



The "T-5" semi-automatic torch should prove valuable to heavy fabricators in applications such as plate-edge preparation or cutting stainless plate. By butting two plates together and gouging along the seam, a smooth "U" groove is produced—and two plates are prepared in a single operation. The T-5 model, mounted on a standard cutting machine, melts metal with the electric arc; compressed air blows it away. *Arcair Co.*

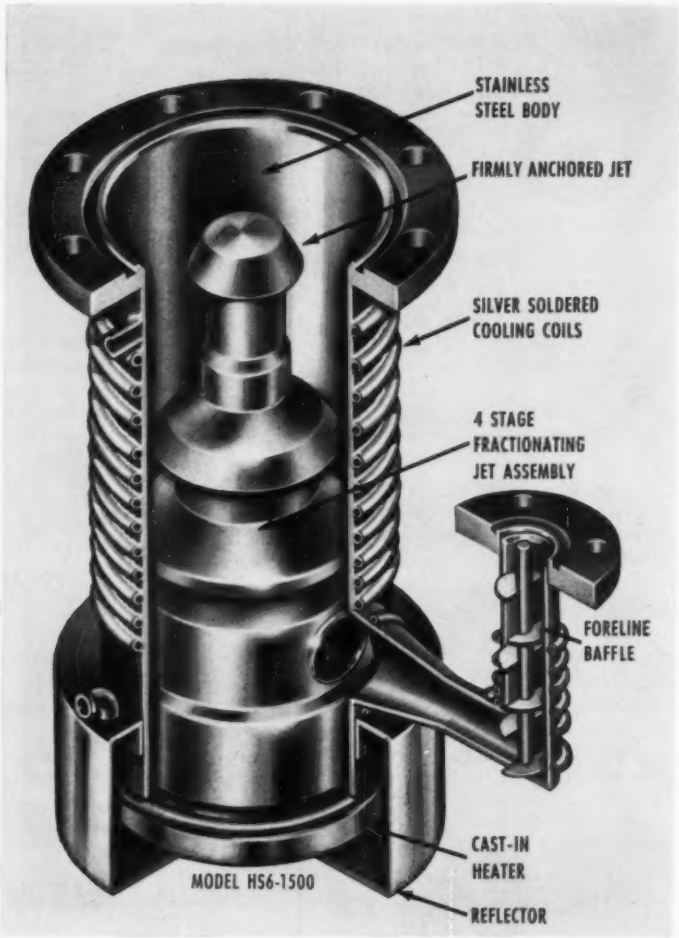
For further information circle No. 941

Engine-Driven Welder

Air Reduction Sales Co. announces an engine-driven welder designed to give dependable service with minimum maintenance in rugged applications. Rated at 250 amp., the unit is driven by a 4-cycle, three-cylinder, direct-injection diesel engine. It can be used as a combination d-c. welder/a-c. power plant or solely as a d-c. welder.

CLEANER HIGHER VACUUM FASTER...

in your system



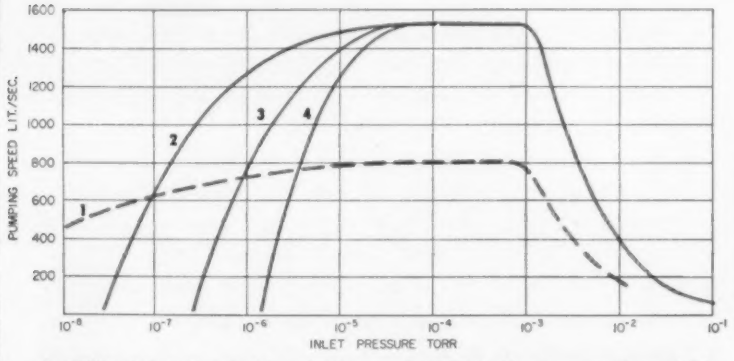
Compare these advantages:

- **HIGH SPEED:** 1500 liters per second.
- **HIGH FOREPRESSURE TOLERANCE:** 700 microns Hg.
- **LOW BACKSTREAMING:** Less than 0.03 mg/cm^2/min.
- **LOW ULTIMATE PRESSURE:** To 10^{-10} mm. Hg. in UHV dome.
- **INSENSITIVE TO POWER AND WATER VARIATIONS.**
- **REQUIRES ONLY 10 C. F. M. MECHANICAL BACKING PUMP.**

The new HS6-1500 fractionating diffusion pump is guaranteed to out perform any other 6″ pump on the market. Compared with its predecessor it offers greater convenience, less maintenance, and lower cost operation.

The new model HS6-1500 costs only $525.00.

Send for our free catalog containing speed curves, or order your new HS6-1500 pump today.



1. DC704, Baked Out Stainless Steel Dome, Metal O-Rings, Liquid Nitrogen Cold Trap.
2. DC704, Metal O-Rings, Stainless Steel Dome.
3. DC704, Neoprene O-Rings, Mild Steel Dome.
4. Narcoil 40® Neoprene O-Rings, Mild Steel Dome.

NRC

NRC EQUIPMENT CORPORATION

A Subsidiary of National Research Corporation

160 Charlemont Street, Dept. 1-C
Newton 61, Massachusetts

Diesel power minimizes the fire hazard in locations such as off-shore oil drilling rigs, tunnels, mines, on shipboard, or wherever gasoline is prohibited.

For further information circle No. 942 on literature request card, p. 48B

AC/DC Metal-Cutting Electrode

The "ChamferTrode" electrode retains its efficient performance, when used with d-c. equipment, and gives equal performance with a-c. welders without cycling or arc cutout. The electrode provides a high-velocity blast for removing molten

metal; oxygen or compressed air is not required. Applications include chamfering, leveling, grooving, and rough cutting of most metals, including hard alloys which are difficult to torch cut. *Eutectic Welding Alloys.*

For further information circle No. 943 on literature request card, p. 48B

Inspection and Testing

Extended-Range Recorder

Five automatic steps of zero suppression allow this unit to measure unknown and widely varying levels of potential. As a variable input exceeds or goes below span, the scale is automatically extended or contracted. Any span from 2 mv. to 250 mv. may be selected; total span is 500 mv. A special "step" pen indicates at which step of zero suppression recorder is operating. Accuracy is ¼ of 1% of entire span; sensitivity is 1/10 of 1% of each span. *Wheelco Industrial Instruments Division.*

Circle No. 944 on request card

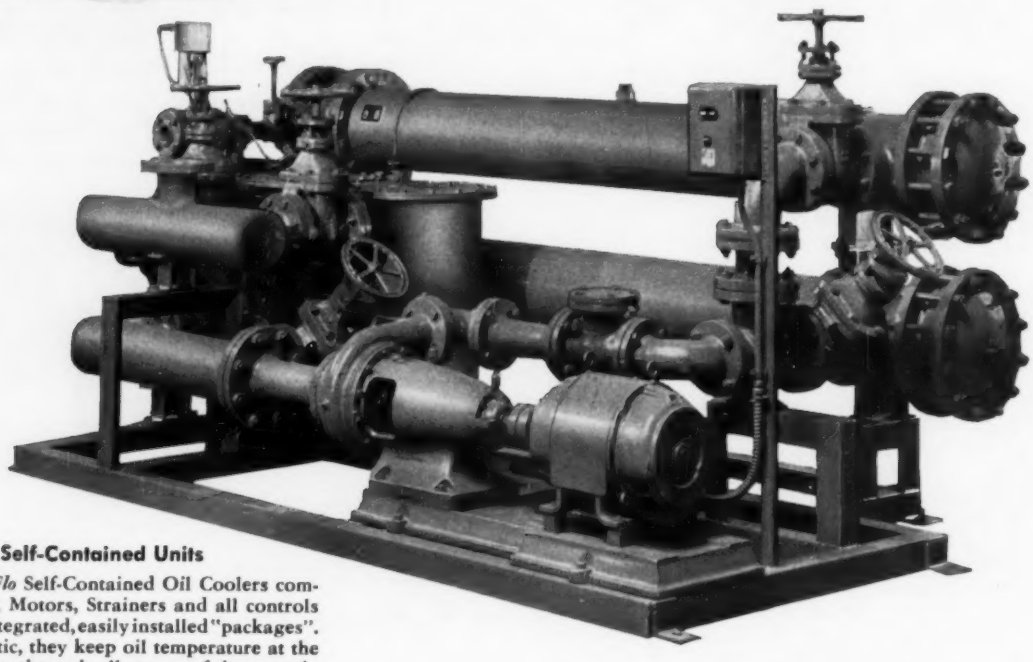
HOW MUCH IS *Faulty Quenching* COSTING YOU?

The quenching stage of your heat-treating process is the point which determines . . . (1) the final quality of your product . . . (2) the amount of time and material wasted by below-standard rejects . . . and (3) your ultimate operating costs.

You can protect yourself against needless production losses by installing a B & G Self-Contained *Hydro-Flo* Oil Cooler. This unit will provide the accurate control of conditions in the quench tank which assures *uniform quality* in the finished product.

The generous heat transfer surface in B & G Self-Contained *Hydro-Flo* Oil Coolers provides large capacities in comparatively small, compact units. They are completely factory assembled, ready for immediate installation and operation.

Tell us about your quenching problems—we'll be glad to offer engineering counsel and recommendations.



Completely Self-Contained Units

B&G *Hydro-Flo* Self-Contained Oil Coolers combine Coolers, Motors, Strainers and all controls into single, integrated, easily installed "packages". Fully automatic, they keep oil temperature at the desired degree through all stages of the quench. Your only responsibility is to connect to the quench tank and water lines.

B&G Oil Cooling Systems may also be purchased as component parts for assembly on the job.

This combined Catalog and Selection Manual gives full information on B&G Self-Contained Oil Coolers. Send for your copy.

B&G

Reg. U.S. Pat. Off.

Hydro-Flo

OIL QUENCHING SYSTEMS

BELL & GOSSETT COMPANY
Dept. GO-16, Morton Grove, Illinois

Canadian Licensee: S. A. Armstrong Ltd., 1400 O'Connor Drive, Toronto 16

Circle 1196 on Page 48-B

Colored Magnetic Powders

Inspecting for flaws in magnetic materials is quicker, easier, and more reliable with "Sonoflux" magnetic powders in three colors. A bright red powder provides good contrast in poorly lighted areas. The yellow powder shows up well against dark scale, as well as heat treated or machined surfaces. The blue-black powder is ideal for surfaces ranging from blast-cleaned grey to highly polished. *Sperry Products Co.*

For further information circle No. 945 on literature request card, p. 48B

Production and Casting Equipment

High-Alumina Refractory Brick

"Korundal XD", a mullite-bonded corundum brick, has higher density and up to 40% lower porosity than other alumina refractories. It shows no subsidence (deformation) after 100 hr. at 3000° F. under a 250-lb. load; other standard bricks show appreciable subsidence, up to 9.6% (photo). Spalling loss is negligible in 3000° F. panel-spalling test. The bricks hold up very well in such high-temperature applications as slab-heating furnaces and checker chambers. *Harbison-Walker Refractories Co.*

For further information circle No. 946 on literature request card, p. 48B

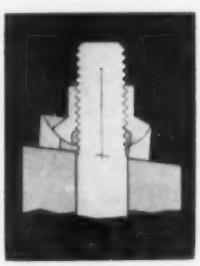
Seals for Vacuum-Furnace Tubes

A dependable universal seal for ceramic furnace tubes in high-temperature vacuum or atmosphere furnaces is offered by *McDanel Refractory Porcelain Co.* The lightweight seal does not require collars, expensive ground-taper joints or grinding of tube circumference. It is adaptable to many processing systems and is simple to install. Easily removed end plates permit fast loading and unloading of the furnace.

For further information circle No. 947 on literature request card, p. 48B

Parts and Forms for Design and Applications

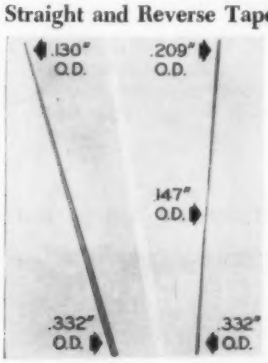
Self-Aligning Locknut



A compensating fastener (SPS SA16) develops rated strength (160,000 psi. tensile) of the alloy steel nut even though seating surface is 8° out of perpendicular. This permits full utilization of high-strength bolts on contoured surfaces without bending (which may lead to early failure). The hex-drive locknut swivels in the spherical seat of a precision-alignment washer. The product is available in diameter sizes No. 10 through ⅜ in., in Class 3B national coarse and fine threads. *Standard Pressed Steel Co.*

For further information circle No. 948 on request card, p. 48B

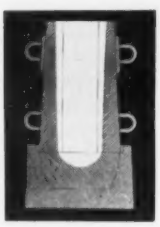
Straight and Reverse Tapered Tubing



Small diameter tapered tubing – 0.080 to 1.500 in. OD with 0.012 to 0.062 in. wall thickness – is available from *Superior Tube Co.* Close tolerances, freedom from ID cracks, and a smooth surface (65 microinch) make this product attractive for thrust chamber tubing in missiles and rockets. Available in lengths up to 10 ft., the tubing can be tapered continuously from one end to the other or can be tapered from the middle to both ends. More than 120 standard and special alloys can be supplied, including carbon, alloy and stainless steels, as well as nickel, copper, and zirconium alloys.

For further information circle No. 949

MEL-TROL®...the important extra you get in *Carpenter* Induction Vacuum Melted Alloys!



New, more refined melting processes such as Carpenter's VACUMELTROL® (induction vacuum) or CONSUMET® (consumable electrode) answers industry's need for better, more dependable steels for critical applications. But in induction vacuum alloys, Carpenter goes a step further. It's called MEL-TROL and it starts with an entirely new, patented mold that builds essential core-to-surface uniformity right into the ingot. Harmful impurities in the molten steel float to the top while the ingot solidifies . . . then are discarded. The result is more complete freedom from segregation and centerline weakness, and the most uniform, dependable alloys you can buy.

Benefits to you: *Improved alloy quality such as cleanness and soundness result in better forgeability, improved machinability and cold forming properties. You get more accurate forgings with better finishes . . . fewer rejects . . . faster production . . . and, most important, true predictable performance in critical alloy components. A wide range of these more uniform, more workable alloys is now available for high temperature and other critical applications. Call your nearby Carpenter representative for the whole story about MEL-TROL and what predictable performing steels can do for you.*

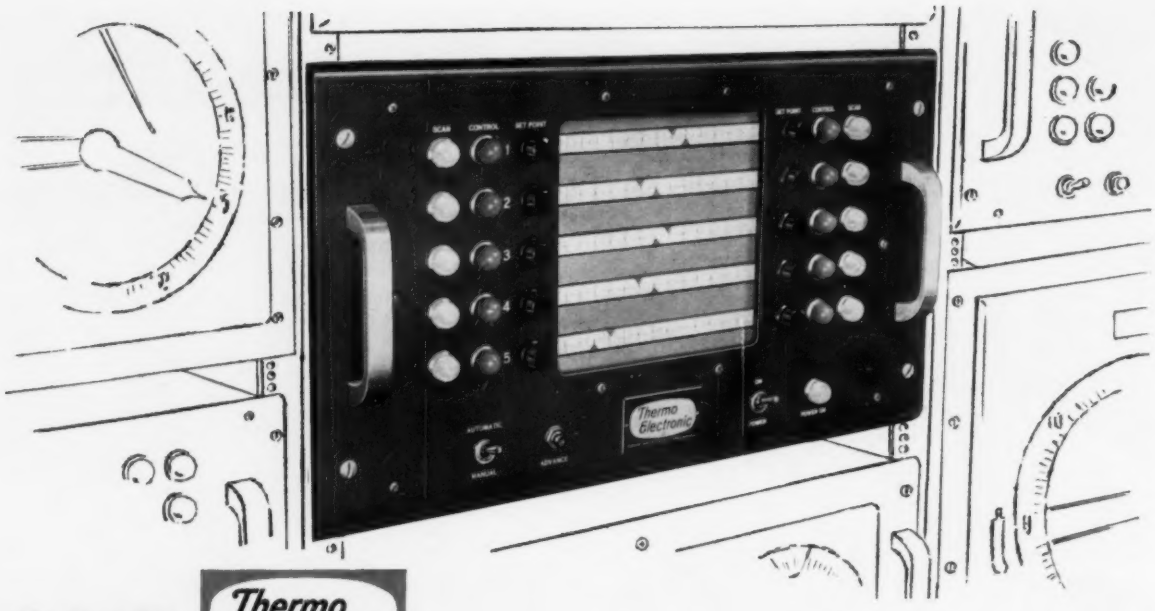
Carpenter steel

you can do it ***consistently*** better with Carpenter Specialty Steels for specialists

The Carpenter Steel Company, Main Office and Mills, Reading, Pa.
Alloy Tube Division, Union, N. J.
Webb Wire Division, New Brunswick, N. J.
Carpenter Steel of New England, Inc., Bridgeport, Conn.

Circle 1198 on Page 48-B

Circle 1199 on Page 48-B



ONE Thermo Electronic Multi-Point Controller

Controls TEN Process Temperatures

One, compact "Thermo Electronic" Multi-Point Controller gives you, sensitive, accurate, automatic . . .

- Two position (off-on) control of up to ten separate process temperatures; also controls flow, pressure, pH, Strain gages, and other operations.
- Three position control of five separate processes!
- Single point constant control of any critical process!
- Manual-Balance Indication of exact process conditions!
- Monitoring of extra points or those already under control!

Ten In One

One instrument does the job of ten individual controllers. You save—40 to 60% of initial cost—up to 75% of panel space —cut installation time and cost—minimize maintenance!

Clean, Simple, Functional Design

The "Thermo Electronic" Multi-Point Controller has front-set controls for easy operation. Routine maintenance is also done from the front, without removing unit from panel or relay rack. Available in either potentiometer or bridge measuring circuits, with an extremely stable constant voltage supply, the instrument provides long-lived, trouble-free control of practically every process suitable to off-on control action. Sensitivity is 15 microvolts independent of scale span—Accuracy is ±0.5% of scale span.

Operation

Sensing element input signals are compared, in sequence, to individually adjustable slide-wire set-points. Signal deviations are amplified by the "Thermo Electronic" high-gain relay control amplifier, and used to actuate load relays connected to the points being controlled.

Scanning sequence is governed by a stepping switch and electronic timer. Scanning rate—3 seconds per point. Other scanning speeds are available by simply changing one carbon resistor.

Ten white lights on the instrument panel show scanning position—ten red lights show process condition. Ten knobs permit adjustment of individual set-points on the range scales. Ranges are available for thermocouples, resistance temperature detectors and other types of suitable transducers.

Maintenance Is Easy

The instrument slides forward on built-in tracks. Simple adjustment and inspection is easily accomplished from the front. The plug-in or screw-terminal components are easily replaced—fully protected from dirt and corrosive atmosphere. The whole instrument is gasketed to further protect components.

Safety Engineering

Critical circuitry is fused against overloading. A failsafe circuit is provided to protect processes against thermocouple burn-out and amplifier component failure.

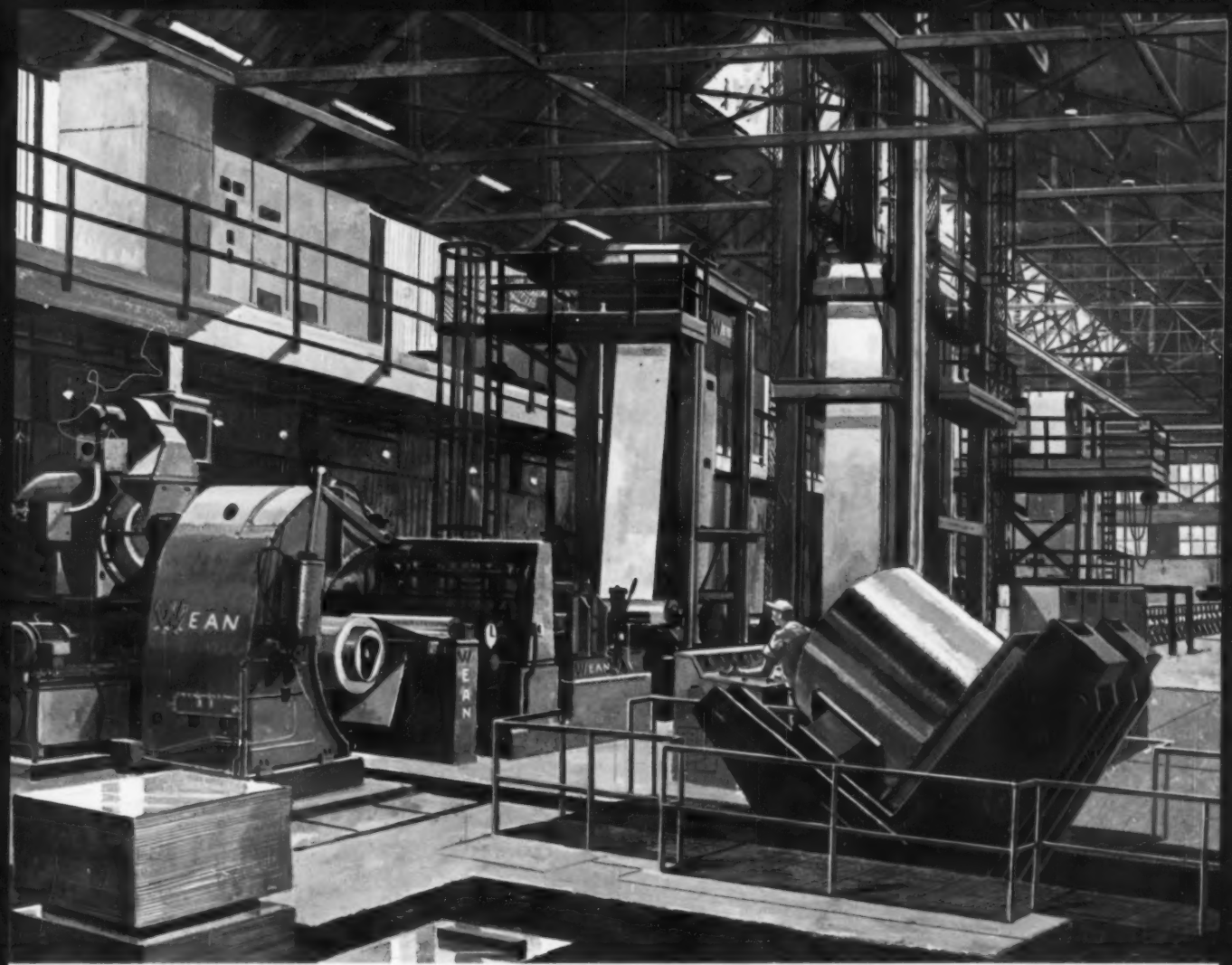
Write today for Instrument Section 52-16

Thermo Electric

Temperature Measuring Systems and Components

THERMO ELECTRIC Co., Inc., Saddle Brook, New Jersey
In Canada: THERMO ELECTRIC (Canada) LTD., Brampton, Ont.

Circle 1200 on Page 48-B



PORTRAIT OF PROGRESS: *Wean No. 2 Alkaline Tinning Line at Granite City Steel Company's Granite City Works*

Granite City Increases its Range of Tin Plate Widths with New Wean Alkaline Line

To supply the full range of coil widths required by the can manufacturing companies it serves, Granite City Steel Company recently installed this Wean alkaline-type tinning line.

Capable of handling coils up to 40,000 lbs. with an outside diameter of 72", this line is designed to process tin plate at speeds up to 1200 fpm. The line can accommodate strip from 18" to 38" in width and from .003" to .015" in thickness.

The new Wean line has been designed to economically produce differential plating, providing more versatility in meeting customer requirements. Strip storage is provided in looping towers at both the entry and exit sections of the line in order to maintain constant flow of material through the processing section.

During its three-decade partnership with the steel industry, Wean Engineering Company has designed more than 80% of all electrolytic tinning facilities in operation today. We invite you to put this experience to work on your next tinning line project.

THE WEAN ENGINEERING COMPANY, INC. · WARREN, OHIO

SYLVANIA FIRES POINT-BLANK

... at transforming research for the military into tools for industry

At 4600°F. gold turns to liquid. Chromium boils. Silver vaporizes. But molybdenum stays solid.

At Sylvania, such high temperatures help our scientists turn defense research on tungsten and molybdenum into practical answers for industry.

For instance, not long ago we devised a new method in which refractory metals are produced as powder of controlled particle size. This powder is isostatically pressed at high pressure and then sintered at high temperatures. Result? Ingots, bars—even intricate shapes—can be produced more efficiently, with more uniform compaction.

Why not take a good look at refractory metals to answer your needs. The identical properties that solve the problems of throat inserts for rockets and missiles can pay *you* dividends in die-casting dies and cores, hot-work tools, molds, and in many other ways.

Want the full story? Or experienced technical help in proving out your special ideas? Write Chemical & Metallurgical Division, Sylvania Electric Products Inc., Towanda, Pennsylvania.

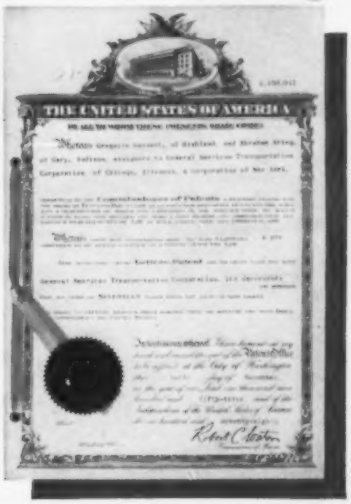
SYLVANIA

Subsidiary of **GENERAL TELEPHONE & ELECTRONICS**

Circle 1277 on Page 48-B

a Reminder

to those who use chemical nickel alloy plating:



There is only ONE

Kanigen®

and 29 patents prove it

There are no substitutes for Kanigen—no other process that applies a hard, corrosion-resistant nickel alloy coating without the use of electricity as Kanigen does.

With Kanigen, you can plate anything from a small relief valve to a 20,000 gallon tank car with a virtually non-porous, uniform coating.

How can you be sure of getting Kanigen? Only one way—by calling General American or one of its licensees. For further information write:

Kanigen Division

GENERAL AMERICAN TRANSPORTATION CORPORATION

135 South LaSalle Street
Chicago 3, Illinois
Offices in principal cities

LICENSEES

INDUSTRIAL KANIGEN CORPORATION
1421 Park Avenue
Emeryville, California

KEYSTONE CHROMIUM CORPORATION
1095 Niagara Street
Buffalo, New York

KEYSTONE METAL FINISHERS, INC.
22 Raydol Avenue
Secaucus, New Jersey

Circle 1201 on Page 48-B

Meet our new baby giant . . . *the M-G Powered INDUCTO INTEGRAL 15*

. . . you'll never again be satisfied with Spark-Gap Melters

Inductotherm now offers the greatest space-saving, most economically-operated induction melting system in history. Once you've compared the Inducto Integral 15, you'll never be satisfied with a spark-gap converter. What's more, the 15-kilowatt Integral 15 has the same melting capacity as 20-Kw spark-gap units.

Compare Installation The entire unit occupies only 35" x 40" of floor space. The motor-generator, capacitors, transformers, and all controls are packaged in a single, compact console. Completely pre-assembled and pre-tested before delivery . . . all you do is tie-in power and water lines and you're ready to start melting. Radio shielding problems are eliminated.

Compare Operation Whatever your melting problem . . . in small foundries, in research laboratories . . . you achieve optimum power for fast, efficient melting with minimum metal loss. In addition, the Integral 15 easily maintains a balanced 3-phase load . . . you can connect two furnaces to one power control . . . and it's readily adapted for vacuum melting.

Compare Maintenance No more hydrogen to purchase, store, feed, and dispose. Moreover spark-gap converters operate at extremely high voltages with peaks up to 20,000 volts, while the Integral 15 operates at a constant 220 or 440 volt coil voltage. Safety factors increase, . . . arcing problems drop almost 99 percent. Costly mica insulation between coils is eliminated. In fact, the *only* maintenance needed is routine lubrication.

Compare Cost The Integral 15 costs a little more than spark-gap units. But you start saving money the minute you start operation . . . in time, metal, maintenance and power consumption. You can amortize the cost differential in a matter of months. And your savings are the same whether you purchase an Integral 15 outright or use Inductotherm's unique rental or lease-purchase plans.

Compare the Facts We'll gladly send you complete details on the Integral 15. Write for Bulletin 20-15. Other Inducto "Integral" models available with capacities of 30, 50, and 100 Kw. Address: Inductotherm Corporation, 412 Illinois Avenue, Delanco, New Jersey.

INDUCTOTHERM

Special Trade-In Offer

Realizing that the Integral 15 obsoletes many spark-gap units just a few years after purchase, Inductotherm plans to share this early obsolescence with their customers by offering a trade-in allowance of 50% of the original purchase price of 20 Kw Inducto spark-gap converters toward the purchase of the new Integral 15. This offer applies only to original purchasers of 20 Kw Inducto Melters and may be withdrawn at any time.

Circle 1202 on Page 48-B

NEW LITERATURE

950. Heat and Corrosion Resistant Cast Alloys

The *Alloy Casting Institute* has issued a 12-p. pamphlet listing 46 technical papers, articles, reprints, and data sheets on alloy

selection, applications, research, fabrication and foundry practice, metallurgical structure and properties, and testing methods for stainless and superalloy castings.

Ferrous Metals

951. 17-4PH Stainless
Armco Steel Corp. has published data on 17-4PH stainless steel; stronger than Type 416, with corrosion resistance in the 18-8 class.

952. Alloy for Electronics
16-p. data sheet on "Moly Permalloy" gives information on testing, hysteresis, heat treating, magnetization curves, core loss, graphs, plus physical, mechanical, and magnetic properties. *Allegheny Ludlum Corp.*

953. Toolsteel Selector
The *Allegheny Ludlum* toolsteel "Steelector" booklet contains selector cards, descriptions of the various toolsteel grades, and explains individual "Data Stock lists" available for each grade.

954. Alloy Steel Booklet
"Quick Facts About Alloy Steels" published by *Bethlehem Steel Co.* Elementary information on steel heat treatment, properties, and microstructures.

955. Stainless Steel
Catalog "*Armco* Stainless Steels" discusses applications for stainless sheet, strip, bar, and wire in 60 analyses and a broad range of sizes and finishes.

956. Austenitic Stainless
8-p. booklet explains nature and occurrence of sigma phase, as well as its chemical composition, identification, and effect on mechanical properties and corrosion resistance. *Electric Steel Foundry Co.*

957. Cold Extrusion
Republic Steel Corp. has released two pamphlets: "Steel for Cold Extrusion" and "Steel for Cold Heading".

958. Vacuum-Melted Steels
Booklet from *Midvale-Heppenstall Co.* gives details on "Midvac" steel produced by the consumable-electrode vacuum-arc-melting process.

959. Alloy Steel Bars
LaSalle Steel Co. will send Data Sheet 22 covering "e.t.d. 150" alloy steel bars which need no heat treating for 150,000 psi. tensile strength.

960. Stainless Steel Products
G. O. Carlson has issued booklet "Producing Stainless Steels . . . Exclusively" which includes sections on stainless steel plates, heads, forgings, and special shapes.

961. Metallurgy Courses
32-p. catalog describes courses available through Metals Engineering Institute. Individual home-study or in-plant extension courses include Elementary Metallurgy, Heat Treating, Welding and Foundry Operations. *American Society for Metals.*

Nonferrous Metals

962. Zirconium Products
"Zirconium Data File" gives information on production of Zr and Hf, melting, wrought products, alloys and properties, fabrication, and applications. *Carborundum Metals Co.*

963. "Handbook of the Alloyist"
Discusses advantages of several groups of alloys used in the electrical and electronics industries. Properties and typical applications are given. *H. K. Porter Co.*

964. Rare-Earth Chemicals
Vitro Chemical Co. offers brochure on rare earth metals, chemicals, and alloys—thoria, gadolinium oxide, cerium and scandium chemicals, and rare earth-magnesium alloys.

965. Nickel Alloys
International Nickel Co. has application data and engineering information on nickel, its alloys, and the various grades of stainless for unusual conditions of stress, fatigue, heat or cold, or corrosion.

966. Cobalt and Nickel-Base Alloys
4-p. data sheet lists physical and mechanicl properties, corrosion resistance, thermal treatments, fabricating data, available forms, and applications of 13 alloys. *Cobalt Information Center.*

967. Rare-Earth Metals
Brochure from *Lunex Co.* contains information on high-purity rare earth metals including neodymium, yttrium, and lanthanum.

968. Copper-Base Alloys
Special Alloys Kit No. 13 contains information on alloys possessing high hardness and wear resistance, good electrical conductivity, or free machining properties. *Mueller Brass Co.*

969. Molybdenum Sheet
A.S.T.M. reprint presents data on properties and applications of molybdenum-base sheet. *Climax Molybdenum Co.*

970. Lead-Lithium Alloy
14-p. report lists published literature on lead-lithium alloys covering investigations carried out over the past 30 years. *Foote Mineral Co.*

971. Molybdenum Products
General Electric Co. will send information on molybdenum products—hearth plates, liners and brackets—used in high-temperature furnaces.

972. Alloys of Copper
Bulletin from *Ampco Metal Inc.* reviews "Ampco" metal applications for corrosion, wear and impact resistance.

973. Lithium Developments
The *Lithium Corporation of America* has information on lithium developments, including additions of this light metal to copper castings to eliminate porosity and improve conductivity.

974. Metallurgy Courses
32-p. catalog describes courses available through Metals Engineering Institute. Individual home-study or in-plant extension courses include Elementary Metallurgy, Heat Treating, Welding and Foundry Operations. *American Society for Metals.*

Heat and Corrosion Resistant Materials

975. René 41
Technical Bulletin No. 86 discusses René 41, the most dependable alloy in use today in the 1200 to 1800° F. range. *Cannon-Muskegon Corp.*

976. Thermal Fatigue
Electro-Alloys Div. will send you a report entitled "The Mechanism of Thermal Fatigue", by H. S. Avery.

977. Super Refractories
The Refractories Div. has published "Super Refractories by *Carborundum*" which contains application and property data on special refractories.

978. Corrosion Data Charts
The corrosive effects of 400 different materials on 16 different alloy systems—including Hastelloys, Monel, Nickel, Inconel, aluminum, tantalum, titanium and zirconium—are shown in data chart published by *Nooter Corp.*

979. Refractory Metal Chart
Offered by *Fansteel Metallurgical Corp.* Lists the properties of the refractory ele-

To request any item listed, circle appropriate number on Reply Card, p. 48-B

NEW HORIZONS IN LEAD

...The *Versatile* Metal

PS-172

ST. JOE **ST. JOSEPH LEAD COMPANY**

250 Park Avenue • New York 17, N. Y.

THE LARGEST PRODUCER OF LEAD IN THE UNITED STATES

Circle 1203 on Page 48-B

ments tungsten, tantalum, molybdenum, and columbium.

980. High-Temperature Alloy

16-p. booklet discusses "Haynes Alloy 56", a lower-cost, high-temperature alloy with good strength and oxidation resistance in the 1200-2000° F. range. *Haynes Stellite Co.*

981. Superalloy

"René 41" is vacuum-induction melted for higher strength and ductility. The alloy can be forged, welded, or formed. Details available from *General Electric.*

982. Refractory Metal Parts

Isostatic pressing and sintering of tungsten and molybdenum powders produces high strength parts for high-temperature —such as rocket nozzles. *Sylvania Electric Products* has the details.

983. Ceramic Coatings

The *Norton Co.* will send complete details on "Rokide" coating process, an economical way to protect parts and equipment against extreme abrasion and temperatures to 4600° F.

984. Molecular Bonding

The molecular bonding process is described in 12-p. leaflet from *Al-Fin Corp.* Aluminum can be bonded to low-carbon or alloy steel, Kovar, cast iron, molybdenum or stainless steel.

985. Nickel-Base Alloy

12-p. leaflet presents information on "Hastelloy B", a nickel-base alloy combining excellent high-temperature properties and corrosion resistance. *Haynes Stellite Co.*

986. Zircoa Refractories

Brochure from *Zirconium Corp. of America* details advantages of zircoa refractories for temperatures from 3000 to 5500° F.

987. 1800 to 2300° F. Service

"Supertherm" is a 26% chromium, 35% nickel alloy stabilized with cobalt and tungsten. Application information and other details available from *Electro-Alloys Div.*

988. Heat Resistant Castings

72-p. booklet "Heat Resistant Castings, Corrosion Resistant Castings . . . Their Engineering Properties and Applications". *International Nickel Co.*

989. Carbonyl Iron Powders

28-p. brochure describes physical, chemical and electromagnetic characteristics of eleven types of carbonyl iron powders used in electronic high-frequency cores. *General Aniline & Film Corp.*

990. Diffusion Coatings

Folder from *Haynes Stellite Co.* discusses diffusion coatings—hard, nonporous surfaces for metals and alloys which increase oxidation resistance at temperatures to 2300° F.

991. High-Alloy Castings

Catalog from the *Duraloy Co.* discusses castings for high-temperature (up to 2300° F.) or corrosion resistant applications.

992. Tungsten and Molydbenum

Sylvania Electric Products Inc. has published literature on tungsten and molybdenum—available as billets and ingots for forging, as electrodes for arc casting, or as blanks for machining.

993. Silicon Nitride

Booklet "Silicon Nitride" covers high-temperature and corrosion resistant properties and applications of the material. *Haynes Stellite Co.*

Radiation and Nuclear Materials

994. Nuclear Metals

Brochure describes laboratory and production facilities and other technical services supplied by *Nuclear Metals, Inc.*

Tool Materials

995. Toolsteel Guide

Written by Dr. B. L. Averbach of M.I.T., "Toolsteels", a basic guide to the use of tool and die steels has been published by *Climax Molybdenum Co.*

996. Toolsteels

Bethlehem Steel Co. will send illustrated Booklet No. 532 covering oil and air-hardening toolsteels.

997. Toolsteel Identification

The *Gorham Tool Co.* has published their ninth edition of a 26-p. booklet covering classifications and symbols for identification of high-speed steels.

998. Tool and Die Steel

12-p. brochure contains information on "LO-Air" tool and die steel. Reduces grinding and machining time. *Universal Cyclops Steel Corp.*

999. Machining Aluminum

Flyer from *Baker Gubbins Co.* gives the facts on "No. 505" water-soluble base which makes a stable, white emulsion in water and resists bacterial growth. It sinks chips and prevents caking of fines.

1000. Protective Covers

Bulletin E-60 explains how production tools and products can achieve longer working life with less maintenance by installing "Elasticone" covers over wearing parts. *Central Safety Equipment Co.*

1001. Ballistic Flarer

Cartridge-actuated tool makes possible the flaring of heavy-wall stainless tubing; 4-p. Folder 4392B14 from *Parker Hannifin.*

1002. Metal-Working Tools

24-p. metal-working tool catalog from *Plew Tool Corp.* covers line of cold heading, forming and cutting tools.

1003. Metal-Forming Machines

The Fenn Mfg. Co. has published literature illustrating metal forming machines —drawbenches, tube mills, swagers—that meet the challenge of the 60's.

1004. Hot Work Die Steel

Improved "Hotform" alloy increases die life, minimizes heat checking and cracking. Information from *Vanadium-Alloys Steel Co.*

1005. Abrasive Cut-Off Wheels

Simonds Abrasive Co. has issued a flyer covering resinoid-bonded abrasive cut-off wheels. Recommended grain and grade specifications included.

1006. Die Steels

Data Sheet 10 presents characteristics and applications of "Super Pyrotem", a high-alloy die steel for use in deep drawing applications. *Heppenstall Co.*

1007. Machine-Tool Control

4-p. Bulletin GEA-7209 describes transistorized machine-tool control capable of performing positioning and/or contouring from standard punched-tape program. *General Electric Co.*

1008. Custom Forgings

Bulletin 400 from *A. Finkl & Sons Co.* shows the wide variety of custom forgings produced, and the many facilities for producing them.

1009. Colloidal Dispersions

Booklet "The Biggest Ounce of Protection" discusses colloidal dispersions for improving production and reducing costs. *Grafo Colloids Corp.*

1010. Pinhole Detector

Bulletin 310 explains "Model 371" pinhole detector which automatically inspects for small holes in metal strip and foil up to 40 in. wide running at strip speeds up to 6000 fpm. *Franklin Electronics, Inc.*

1011. Heavy-Duty Coolant

Product data sheet describes physical properties of "Hocut No. 3210", a water-soluble base for heavy-duty machining operations. *E. F. Houghton & Co.*

1012. Machining of Metals

16-p. engineering report, "A Yield Criterion Appled to the Shear-Angle Relationship" by B. N. Colding, is available from *Cincinnati Milling Machine Co.*

1013. Steel-Bonded Carbide Tools

Properties and metallography of steel-bonded carbide tools covered in technical reprint available from *Sintercast Div. of Chromalloy Corp.*

Industrial Heating

1014. Heat Treating Chart

Tempil Corp's four-color chart, "Basic Guide to Ferrous Metallurgy," illustrates forging, burning, annealing, transformation, stress-relieving, nitriding, blue brittle, normalizing, and carburizing ranges, as well as grain size changes vs. temperature.

1015. "Heat Treat Review"

Contains discussion of new developments in high-temperature gas carburizing, including heating curves, photomicrographs of test samples, and illustrations of carburizing equipment (Vol. 11, No. 2). *Surface Combustion Div.*

1016. Furnace Controls

Minneapolis-Honeywell will send details on line of furnace controls, including "Electro-O-Line" unit for position-proportioning control with reset and rate action.

1017. Induction Heating Equipment

56-p. catalog from *Induction Heating Corp.* reviews specifications and applications for induction heating equipment.

1018. Controlled Atmosphere Furnaces

Bulletin K-1 reports on "Kleanmetal" atmosphere furnaces for operation at 1200 to 2000° F. *W. S. Rockwell Co.*

1019. Refrigeration Systems

Data sheet and catalog gives full information on *Harris Mfg. Co.* "Cascade" refrigeration systems for low-temperature industrial uses.

1020. Vacuum Heat Treating

Bulletin 5709A from *C. I. Hayes, Inc.* gives the facts on vacuum furnaces for heat treating exotic metals (tantalum, titanium, columbium) in the 2600 to 4500° F. range.

1021. Radiant Tubes

Leaflet from *General Alloys Co.* reviews advantages (including long life) of wrought-cast radiant tubes.

1022. Salt-Bath Furnaces

Bulletin 700 details the "Cataract Quench" which meets practically any TTT curve requirement with precision. *Ajax Electric Co.*

To request any item listed, circle appropriate number on Reply Card, p. 48-B

ANNOUNCING ANOTHER *NEW* COST-REDUCING

Strain-Tempered® Grade

NOW...THE INDUSTRY'S MOST COMPLETE LINE OF HIGH-STRENGTH COLD FINISHED STEEL BARS

NEW for maximum machinability

Strain-Tempered 4145 Leaded is the easiest-to-machine high-strength alloy bar you can buy. Heat treatment and related distortion corrections after machining are eliminated. Tool life is increased. Both material and processing costs are reduced. Strain-Tempered 4145 Leaded is another money-saving development of Bliss & Laughlin research.

Guaranteed Minimums: 150,000 psi tensile strength; 130,000 psi yield strength; 302 Brinell. Approximate minimums: 10% elongation in 2"; 35% reduction in area.

LOWEST COST for highest strength

Strain-Tempered alloys are also produced to other strength levels at savings from $29 to $87 per ton. Grades like 4140 and 5150, for example, can be produced to individual mechanical property specifications such as: 115,000, 125,000 or 145,000 psi minimum tensile strength; 95,000, 105,000 or 125,000 psi minimum yield strength; 217/255, 269/321 or 275/325 Brinell and 27/34 or 28/36 Rockwell "C". Various combinations of severe cold working and special furnace treatment tailor the material to your exact requirements.

PAY ONLY for the grade needed

As in the case of Strain-Tempered Alloy, Strain-Tempered Carbon Bars are available in a variety of grades. You pay only for the grade which meets your machinability needs. These bars offer a unique combination of high strength, long wearability, good ductility and a low level of residual stresses.

Guaranteed Minimum: 100,000 psi yield strength for standard Strain-Tempered C1144.

ASK FOR FOLDERS

NEW Strain-Tempered 4145 Leaded Now in Stock at Steel Service Centers

Circle 1204 on Page 48-B

Specialists in Finish, Accuracy, Straightness, Strength and Machinability

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GENERAL OFFICES: Harvey, Ill. • MILLS: Harvey, Detroit, Buffalo, Los Angeles, Seattle, Mansfield, Mass.

Leading Independent Producer of Cold Finished Steel Bars

BL-812

1023. Temperature Controls
Brochure is available from *Leeds and Northrup* on "L&N" temperature controls for modernization or plant expansion.

1024. Electric Furnace
L and L Mfg. Co. will send information on "Dyna-Trol" furnace for applications such as heat treating, drawing, and glass annealing. Temperatures from 300 to 2300° F.

1025. Electric Heating Elements
24-p. Bulletin H illustrates line of "Globar" silicon carbide elements for various heat processing operations including forging, sintering, brazing, annealing and melting. *The Carborundum Co.*

1026. Heat Treating Salts
Eliminate scaling and decarburization in heat treating without special atmosphere by using salt baths. Data supplied by *American Cyanamid Co.*

1027. Furnace Retorts
"Cor-Wall" rolled alloy retorts last longer; the bellows effect resulting from lightweight corrugated construction absorbs thermal stresses. Get the facts from *Stanwood Corp.*

1028. Hump Furnace
Bulletin HMB-60 from *Harper Electric Furnace Corp.* explains hump-type mesh belt furnace which provides low dew point atmospheres for continuous brazing.

1029. Industrial Ovens
Bulletin 157 discusses accurate, dependable low cost heat treating with *Young Brothers* ovens. Batch and conveyor types up to 1000° F.

1030. Furnace For Toolsteels
The "Diamond Block" toolsteel furnace provides a truly neutral atmosphere for high-speed, high-carbon, high-chromium and air hardening steels. Information from *Sentry Electric Furnaces Co.*

1031. Gantry Furnace
12-p. catalog describes line of standard furnaces plus automatic gantry furnace for rapid production heat treating of large missile components. *Pacific Scientific.*

1032. Temperature Regulators
Catalog 360 illustrates temperature-regulating devices capable of controlling air or liquid temperatures within a fraction of a degree. *American Instrument Co.*

1033. Induction Melting
Induction melting provides precise control for powder production by metal atomization. Send for copy of "The Case For Induction Melting" by *Ohio Crankshaft Co.*

1034. Automatic Furnaces
Catalog from *American Gas Furnace Co.* details the advantages of "Automotion" automatic heat treating furnaces, both reciprocating hearth and rotary retort units.

1035. Pyrometer Accessories
Brochure from *Bristol Co.* covers line of pyrometer accessories, including thermocouples, protection tubes, radiation-unit accessories, refractory insulators, and thermocouple extension wire.

1036. Automatic Vacuum Unit
Ipsen Industries, Inc. has complete data and specifications on Model "VFC-300" automatic vacuum heat treating unit.

1037. Heat Exchangers
Bulletins 120, 124 and 132 contain information on "Niagara Aero" heat exchangers for controlling the temperature of quench baths. *Niagara Blower Co.*

1038. Heat Treating Furnaces
The *Electric Furnace Co.* will send information on fuel fired and electrically heated furnaces for processing any product in any atmosphere.

1039. Gas Burners
"Buzzer" burners need no blowers, power or other equipment to effect combustion; simply connect to available gas supply. Catalog from *Charles A. Hones.*

1040. Induction Heating
Catalog from *Lepel High Frequency Laboratories, Inc.* illustrates line of high-frequency induction heating units for brazing and heat treating applications.

1041. Heat Processing Equipment
Literature from *Selas Corp.* shows how automatic heat processing equipment cuts operating costs, increases production rates and minimizes in-process inventory.

1042. Thermocouple Wells
Minneapolis-Honeywell has published Catalog G100-5 which tells about nine basic types of standard pressure-tight wells, with or without thermocouple assemblies.

1043. Furnace Tubes
The *Pressed Steel Co.* will send booklet detailing the advantages of lightweight fabricated radiant tubes. Saves furnace time and fuel and promotes uniform flow of gas.

1044. Vacuum Furnaces
8-p. Bulletin 800, illustrating complete line of vacuum furnaces, has been released by *Lindberg Engineering Co.*

Cleaning and Finishing

1045. Etching and Plating
Brochure from *Eastman Kodak Co.* on etching, chemical milling, and plating with "Metal-Etch Resist."

1046. Metallic Abrasives
Information from *Cleveland Metal Abrasive Co.* on iron and steel abrasive shot and grit.

1047. Sodium Nitrite Treatment
Solvay Process Div., Allied Chemical Corp. will send booklet "Sodium Nitrite for Rust and Corrosion Prevention."

1048. Rust Removal
Service Bulletin No.16B tells how to remove rust or prevent dust . . . safely and economically. *Oakite Products Inc.*

1049. Precious Metal Plating
Brochure from *Sel-Rex Corp.* discusses processes and systems for plating with precious metals.

1050. Nickel Alloy Plating
Chemical nickel plating applies a hard, corrosion-resistant nickel alloy coating without the use of electricity. *General American Transportation Corp.*

1051. High-Temperature Paints
Data sheets from *Speco, Inc.* give the facts on "Heat-Rem H-120A" aluminum paint for applications previously thought unpaintable due to temperature or severe atmospheric conditions.

1052. Citric Acid
30-p. brochure lists grades of citric acid available, physical and chemical properties and applications (including metal finishing) in the metals industry. *Miles Chemical Co.*

1053. Automatic Loading Systems
Frederic B. Stevens, Inc., will send infor-

Circle appropriate number on Reply Card, p. 48-B

You win savings in the long run! *With Vancoram Chromium Alloys.*

True economy is your prize in the long run when you choose from the comprehensive range of Vancoram Chromium Alloys—because there's one 'just right' for every job you do. And buying 'nearly right' just isn't right enough!

Vancoram Chromium Alloys meet specific needs for makers of stainless, heat-resisting, tool and constructional alloy steels, and for the foundry industry. Choose from high-, medium- and low-carbon grades, including EXLO,® a true ferroalloy with high chromium-to-carbon ratio. Vancoram Ferrochromiums and Ferrochrome-Silicons have a well-earned reputation for cleanliness and uniformity. Your VCA representative can help you select the composition 'just right' for you. Vanadium Corporation of America, 420 Lexington Avenue, New York 17, N.Y. • Chicago • Cleveland • Detroit • Pittsburgh

Be sure to visit us at the Hotel Warwick during the A.I.M.E. Open Hearth Meeting, Philadelphia, April 10 to 12.

VANADIUM
CORPORATION OF AMERICA
Producers of alloys, metals and chemicals

VANCORAM

Circle 1206 on Page 48-B

mation on automatic loading systems used in conjunction with automatic barrel plating and processing equipment.

1054. Electrostatic Paint System
8-p. Brochure 100 illustrates centrifugal-type electrostatic paint spray systems and equipment. *Ionic Electrostatic Corp.*

1055. "The Abrasive Workshop"
November issue features an article detailing how die-cast aluminum parts can be ground to close tolerances of flatness, thickness and parallelism with 50% savings. *Carborundum Co.*

1056. Cadmium Brighteners
Conversion Chemical Corp. has issued data sheets covering zinc and cadmium brighteners, wetting agents and purifiers.

1057. Ultrasonic Cleaning
Flyer from *Acoustica Associates, Inc.* describes 40-kc. line of ultrasonic cleaning systems.

1058. Rubberized Abrasives
Cratex Mfg. Co. Inc. offers complete industrial catalog covering rubberized abrasives for micro-deburring, smoothing, cleaning and polishing.

1059. Conversion Coatings
Allied Research Products, Inc. has published technical data file on chromate conversion coatings for finishing zinc, cadmium, aluminum, magnesium, silver, copper, brass or bronze.

1060. Blast Cleaning
Information available from *Pangborn Corp.* on "Rotoblast" cleaning equipment, vibratory finishing equipment, steel shot and grit.

1061. Alkaline Stripper
Bulletin 9651 covers "Ruststripper", a universal tank cleaner . . . removes rust, scale, paint and soils. *Oakite Products.*

Welding and Joining

1062. Welding and Brazing
56-p. catalog and instruction manual covers welding, brazing, soldering and fluxes. Properties, uses and application data included. *All-State Welding Alloys.*

1063. Resistance Welders
12-p. brochure illustrates line of resistance welders — spot, projection, seam, roll-seam, portable welders, aircraft spot and seam, flash, multi-spot and automatic machines. *Federal Machine and Welder.*

1064. Welding Guide
80-p. "Vest Pocket Guide to Better Welds" published by *Hobart Brothers Co.*, gives data on proper welding procedures and techniques, causes and cures of welding troubles, welding symbols, electrodes, definitions, joints, wires and fluxes, and power sources.

1065. MIG Welding
Miller Electric Mfg. Co. has published literature which tells about the "Model CP-2" variable-slope, 200 amp. d-c. welder.

1066. Stainless Brazing
Furnace brazing of stainless parts gives joints as strong as parent metal. *Wall Colmonoy Corp.* will send information on their stainless brazing facilities.

1067. Flash Welder
Asea Electric, Inc., has released a booklet which gives the facts on a tube flash welder. It features automatic internal flash and upset reduction in preformed tube elements.

1068. Flame-Cutting Machines
Linde Co. will send 28-p. catalog illustrating complete line of "Oxweld" flame-cutting machines.

1069. Oxy-acetylene Flame
Two full-color wall charts issued by *Smith Welding Equipment Corp.* show distinctive traits of an oxy-LP gas flame compared to oxy-acetylene flame.

1070. Silver Brazing
Bulletin 20 explains silver brazing and its benefits; includes details on alloys, heating methods, joint design and production techniques. *Handy & Harmon.*

1071. Hardsurfacing
Data Sheet No. 56 "Surfacing Austenitic Manganese Steel With Walmag No. 3 and Walmag No. 8" available from *Wall Colmonoy Corp.*

1072. Automatic Torch
Bulletin NH-142 discusses "Model A-10" automatic torch for MIG and TIG welding and "Model AM-7" gun for semi-automatic welding. *National Cylinder Gas Div.*

1073. Plasma Spraying Process
Brochure 101 explains the plasma spraying process and applications in high-temperature protection, fabrication of parts of "unworkable materials" and deposition of carbide hardfacing. *Plasma Systems Corp.*

1074. Gold-Alloy Preforms
Bulletin Z-108 gives the facts on gold alloy preforms for use as a joining material in semiconductor processing applications. *Accurate Specialties Co.*

1075. Temperature Crayons
Pamphlet from *Tempil Corp.* contains information on "Tempilstik", a simple and accurate means of determining preheating and stress-relieving temperatures in welding operations.

1076. Chromallizing Process
Chromallized molybdenum thermocouple housings will withstand temperatures to 4100° F. This and other chromallizing applications discussed in Bulletin PC. *Chromalloy Corp.*

1077. Welding Torches
8-p. booklet describes "Oxweld" mixer-type welding torches capable of welding any metal thickness from 28-gage sheet to heavy plate. *Linde Co.*

Inspection and Control

1078. Information Searching
Brochure discusses documentation service which delivers the world's current metallurgical literature to you every two weeks in digest form. *American Society for Metals.*

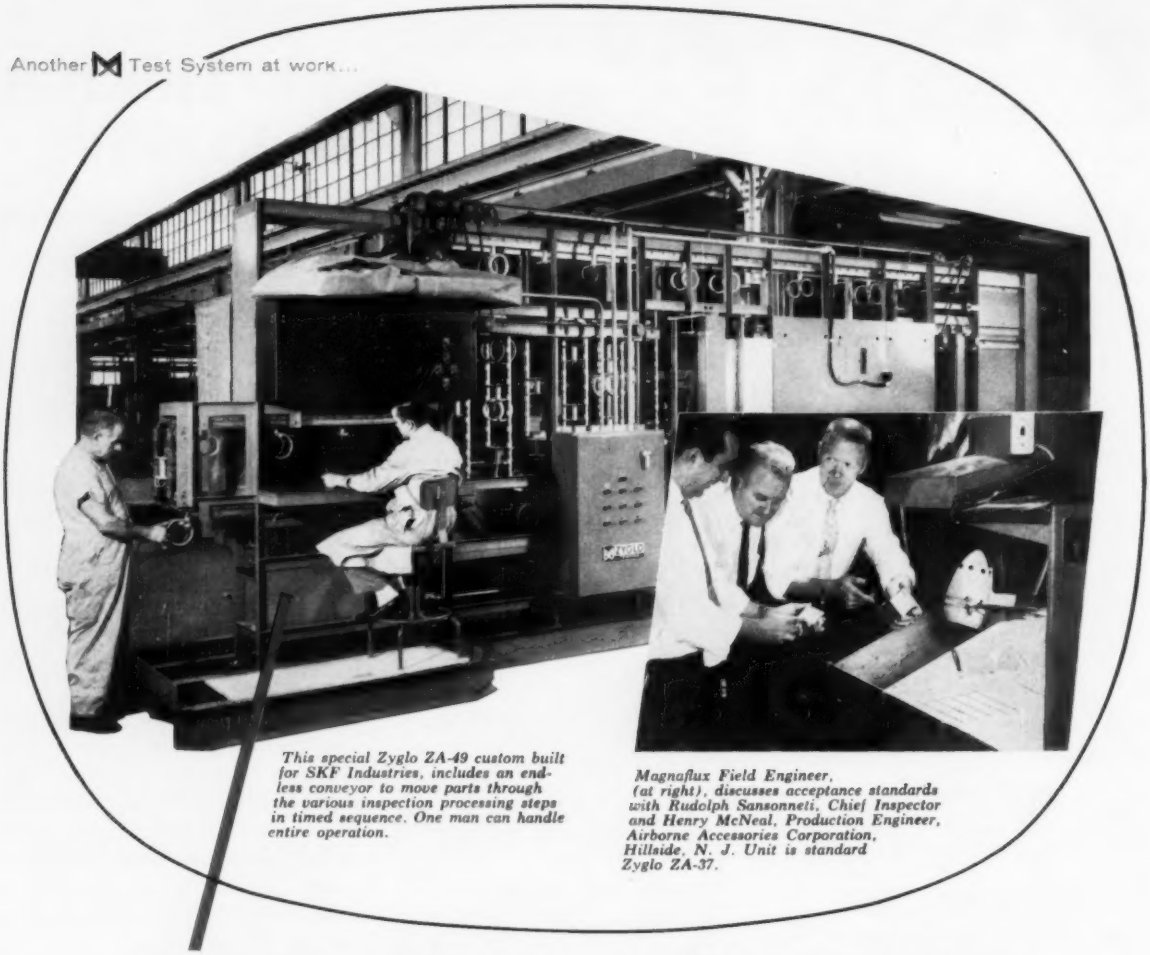
1079. Specimen Mounting Material
The *Fulton Metallurgical Products Corp.* has published a brochure describing "Quickmount", a fast-setting, self-curing specimen mounting material that produces clear mounts without application of heat or pressure.

1080. Scientific Apparatus
Scientific Products has published a 40-p. brochure entitled "S/P Review" (equipment and supply issue). A complete listing of major laboratory equipment and supplies is included.

1081. Metallurgical Microscopes
Information from *Cooke, Troughton & Simms, Inc.* on M12 metallurgical microscope which gives you superior optical performance.

Circle appropriate number on Reply Card, p. 48-B

Another Ⓜ Test System at work...



This special Zyglo ZA-49 custom built for SKF Industries, includes an endless conveyor to move parts through the various inspection processing steps in timed sequence. One man can handle entire operation.

Magnaflux Field Engineer, (at right), discusses acceptance standards with Rudolph Sansonneti, Chief Inspector and Henry McNeal, Production Engineer, Airborne Accessories Corporation, Hillside, N. J. Unit is standard Zyglo ZA-37.

You Save Money Finding Cracks with ZYGLO—Large or Small

Fluorescent Penetrant Test for Nonmagnetic Materials

The big machine above is a specialized, automated Zyglo System with which one man tests up to 375 non-ferrous bearing cages per hour for cracks, porosity, or leaks. It includes complete conveyorized handling and programmed processing, custom engineered and built by Magnaflux. Parts tested range from ¾" I.D. to 10" O.D.

The inset shows a hand-operated Zyglo ZA-37 used to test critical aircraft parts—from small screws in batches, up to 9-lb., 6" x 18" components.

Dozens of other Zyglo Units and Systems—larger, smaller and in between these examples—are available in standard, productionized-standard and specially engineered installations. Whether you need to test thousands of small parts per hour, a few large ones, or any combination, there's a Zyglo to meet *your* specs and savings objectives.

Further, no less than 26 precisely formulated Zyglo Test Materials provide 100% reproducible results at any degree of sensitivity you require. You never need over or under inspect with Zyglo.

For further information on Zyglo savings and quality standardization, phone our local Magnaflux Field Engineer, or write Magnaflux Corporation, 7322 W. Lawrence Avenue, Chicago 31, Illinois.

Ⓜ MAGNAFLUX CORPORATION
TEST SYSTEMS
A SUBSIDIARY OF GENERAL MILLS
General Mills

Ⓜ Test Systems Include MAGNETIC PARTICLE, FLUORESCENT PENETRANT, THERMOGRAPHIC, EDDY CURRENT, ULTRASONIC, STRESS ANALYSIS, RADIOGRAPHIC TESTING, DYE PENETRANT & MAGNETIC FIELD

1082. Universal Tester
Catalog from *Instron* sets forth details on a Universal Tester and other materials testing equipment.

1083. Diffraction Equipment
Pamphlet from *Radio Corp. of America* describes line of X-ray diffraction and spectroscopy equipment including an X-ray vacuum spectrometer for analyzing the lighter elements (below atomic number 22).

Production and Casting

1103. Endothermic Generator
Rolock Inc. has literature covering an endothermic gas generator. Features complete reversibility and self-cleaning of catalyst beds.

1104. Steel Castings
Esco Corp. has issued 24-p. Catalog 175DS entitled "Custom Alloy Steel Castings" which contains data on heat, corrosion and abrasion resistant alloy steels.

1105. Gas Proportioners
Gas proportioner systems which mix various gases at the point of application are discussed in Information Report No. 20 from *National Cylinder Gas Div.*

1106. Aluminum Melting Furnace
Bulletin SEC-12 lists the advantages of an aluminum melting and holding furnace for use in permanent mold, sand or die-casting plants. *Sunbeam Equipment Corp.*

1107. Ramming Mix
H. K. Porter Co. announces the availability of literature on "Kilmag Cladex" a burned magnesite-chrome basic brick with built-in expansion characteristics.

1108. Ferrocolumbium Additions
Vanadium Corp. of America has published literature on "Exothermic Ferrocolumbium" which cuts production costs due to high recovery rates (90% or better).

1109. Vacuum "Micronicle"
Periodical contains news about electron beam welders and other information for product improvement with high-vacuum equipment. *NRC Equipment Corp.*

1110. Alumina Refractories
Data sheets contain information on properties and applications of B & W refractories, firebrick and ramming mixes. *Babcock and Wilcox Co.*

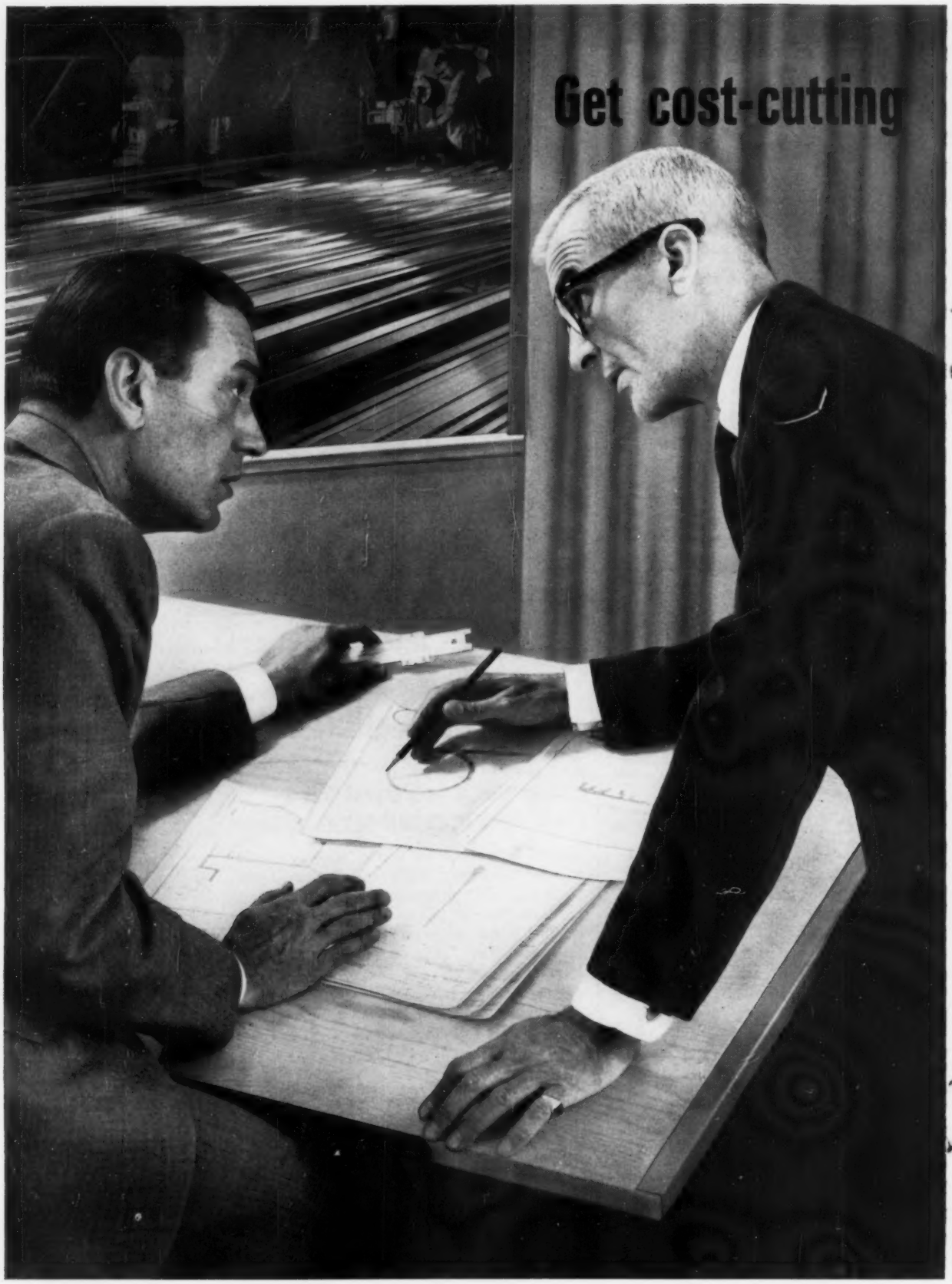
1111. Hydrogen Atmosphere
Pamphlet from *Hamler Industries, Inc.* explains their coordinated ammonia service, which can save you up to 50% of the cost of buying pure hydrogen.

1112. Industrial Blowers
Catalog 126B contains complete specifications on industrial blowers in standard capacities of ⅛ to 1000 hp., up to 20,000 cfm., and 4 oz. to 10 lb. pressure. *Spencer Turbine Co.*

1113. Vacuum Pumps
Flyer from *F. J. Stokes Corp.* gives the facts on "Series H Microvac" pumps. Vacuum slide calculator also available.

1114. Refractory Cement
Information offered by *Universal Atlas Cement Div.* on aggregates, proportions and methods of making concrete with "Lumnite" cement.

1115. Universal Seals
Leaflet from *McDanel Refractory Porcelain Co.* on universal seals for high-temperature vacuum furnace tubes.


Get cost-cutting

engineering help when you specify extruded aluminum products

Call in your nearby independent fabricator . . .

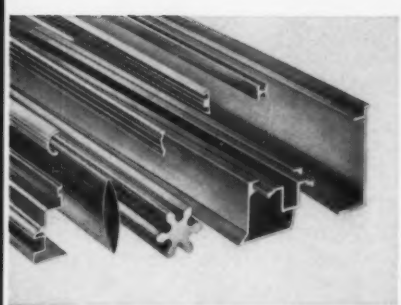
Supplied with quality ALCAN aluminum by Aluminium Limited

The practical everyday help you need in aluminum application may be just around the corner—at your nearby aluminum extruder.

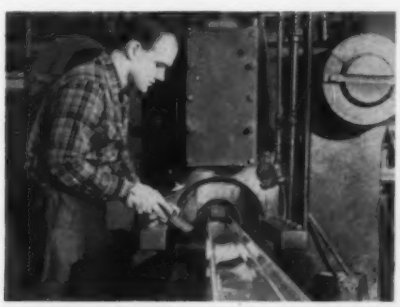
You'll find he's experienced! With knowledge gained through years of working with aluminum—he can help you design extruded shapes best suited to trouble-free production . . . peak end-product performance. He can help in alloy selection, too, offering you a wide variety of aluminum alloys formulated by Aluminium Limited.

Your independent aluminum extruder also offers more personalized service . . . your business is important to him. Even on small orders, he will give you the quality work, attention to detail and prompt delivery that assure your repeat orders.

Call in your aluminum fabricator on your next extrusion order. Let him estimate on cost and delivery. Or, if you prefer, we'll be pleased to send you a list of leading independent aluminum extruders in your area.



Any shape . . . the right alloy. Your nearby extruder can turn out aluminum in a wide range of shapes to meet your most exacting requirements. He also works with you in choosing from a variety of ALCAN aluminum alloys.



Modern equipment. Investigate the facilities offered by your aluminum fabricator—you'll find him well equipped to serve you. His facilities, experience, location, and his personalized service make him your best source of extruded aluminum products.

Fast, reliable delivery. Because he's nearer to your plant, your aluminum fabricator can arrange production schedules to suit your needs. He can also work more closely with you in estimating, planning and engineering.

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Gentlemen: Kindly send me a list of independent aluminum extruders in my area.

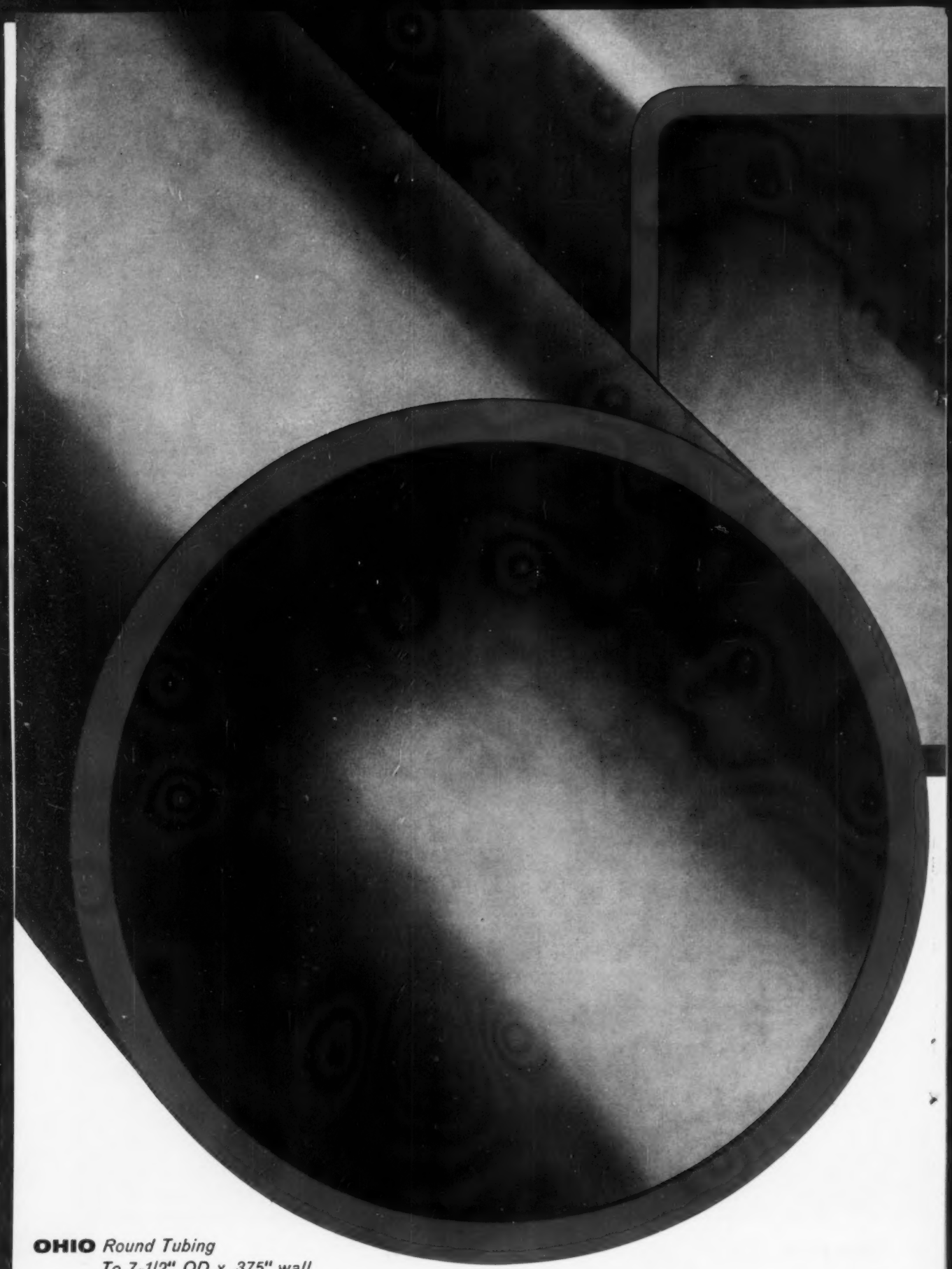
Name_____ Title_____

Firm_____

Address_____

City_____ Zone____ State_____

Circle 1211 on Page 48-B



OHIO *Round Tubing*
To 7-1/2" OD x .375" wall

A-3573A

OHIO *Square Tubing*
To 6" x 6" x .259" wall

OHIO *Rectangular Tubing*
To 7-1/2" major diameter x .259" wall
Typical 4" x 6" x .259" wall section illustrated

Announcing Mechanical — Pressure — Cold Drawn

OHIO QUALITY WELDED STEEL TUBING

in larger sizes...heavier wall thicknesses

OHIO SEAMLESS TUBE

Division of Copperweld Steel Company • **SHELBY, OHIO**

Seamless and Electric Resistance Welded Steel Tubing • Fabricating and Forging

New sizes and heavier wall thicknesses of Ohio Quality Welded Steel Tubing (up to 7½" OD) now parallel the sizes of famous Ohio Seamless Steel Tubing. That means — now more than ever — there's a type and size of Ohio tube to fit your special requirements exactly. And since we make both types, we're in a position to recommend the best type for your own particular needs. Ohio Tubing — either welded or seamless — is just "made to order" for your product.

Circle 1212 on Page 48-B

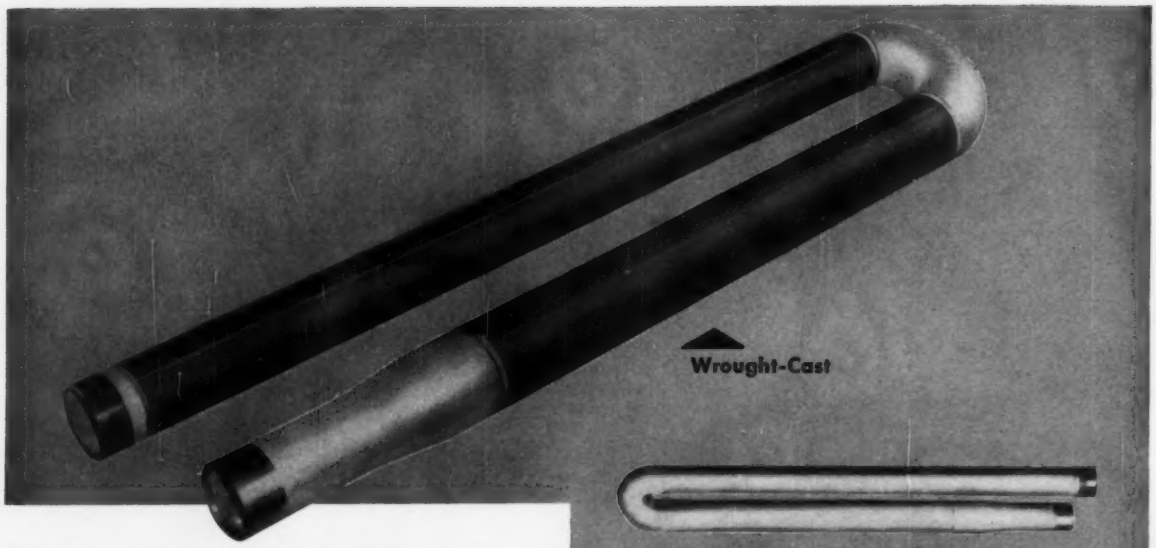
Cut along line and send air mail to save time.

RUSH me, without obligation, latest information on new larger sizes and heavier wall thicknesses of Ohio Welded Steel Tubing.

Name_____ Title_____

Company _____

Address_____ City_____ State_____



Unique General Alloys'

WROUGHT-CAST RADIANT TUBES

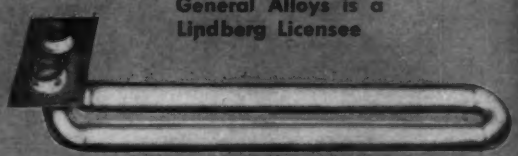
give consistent long life

General Alloys' combination *Wrought-Cast* Radiant Tube Assemblies give consistent long life because they combine a *cast* return bend with straight tubes made from *rolled and welded plate.*

This design utilizes the erosion resistance of the casting where it is most needed . . . at the return bend. The uniform wall section of the plate forming the straight tube, and its smooth interior surface, prevent "hot spots" and "carbon build-up" that are the prime causes of erratic tube life.

General Alloys Company is unique as a major producer of *both* castings and fabrications and therefore can recommend, without bias, the type of construction best suited for your needs.

For complete data, quotes, or engineering service contact the office nearest you . . . or write General Alloys Company, 401 West First Street, Boston 27, Massachusetts.



General Alloys Company also produces entirely cast, as well as entirely fabricated radiant tube assemblies, in all the heat resisting alloys for every purpose and in every size.

Ask about how our tube repair service can save you money!

GENERAL ALLOYS CO.

the only producer of both heat resisting castings and fabrications

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518 American Life Bldg.

BUFFALO 23, New York
General Alloys Company
P.O. Box 2365

CHICAGO, Illinois
General Alloys Company
224 S. Michigan Ave.

CLEVELAND 15, Ohio
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2036 East 22nd Street

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Tracy C. Jarrett
P.O. Box 7857

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General Alloys Company
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Wm. E. Brice Co.
303 Bastrop St.

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2302 N. Meridian Street

LOS ANGELES, Calif.
National Furnace Co., Inc.
5251 Tweedy Blvd.
South Gate, California

LOUISVILLE 7, Kentucky
The George O. Desautels Co.
4003 Hyslife Avenue

MEMPHIS 12, Tenn.
F. G. Donedrio
463 Scott St.

MUNCIE, Indiana
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405 Wyser Bldg.

NEW ENGLAND
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Hayward Mill Road
West Concord, Mass.

NEW YORK 7, New York
General Alloys Co.
80 Church Street

PHILADELPHIA, Pa.
General Alloys Co.
P.O. Box 251, Southampton, Pa.

PITTSBURGH 15, Pa.
Vincent C. Leatherby
Sharpsburg, Pa.

ST. LOUIS 16, Missouri
Associated Steel Mills, Inc.
P.O. Box 1986, Meramec Station

Circle 1213 on Page 48-8

The ASM is the communications center for technical information wherever metals are produced, processed, fabricated, designed, tested and applied. Metal Progress, monthly engineering magazine of the Society, reports on engineering developments in these 11 major technological areas:

FERROUS METALS

NONFERROUS METALS

HEAT- AND CORROSION-RESISTANT AND ELECTRICAL MATERIALS

RADIATION AND NUCLEAR MATERIALS & EQUIPMENT

TOOL MATERIALS, CUTTING AND FORMING EQUIPMENT

INDUSTRIAL HEATING EQUIPMENT AND SUPPLIES

CLEANING AND FINISHING EQUIPMENT AND SUPPLIES

WELDING AND JOINING EQUIPMENT AND SUPPLIES

INSPECTION AND CONTROL EQUIPMENT AND SUPPLIES

PRODUCTION AND CASTING EQUIPMENT AND SUPPLIES

PARTS, FORMS AND SHAPES FOR DESIGN AND APPLICATIONS

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March, 1961 issue
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Catalogs and Bulletins are available from a *scrutinized* and up-to-date list of manufacturers' literature, conveniently indexed under the 11 major Engineering Areas.

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Please Include Your Name and Address!

These typical 25 took a total of 152

HERE ARE 25 DISCRIMINATING BUYERS WHOSE OVER 152 ORDERS AND REORDERS PROVE COMPLETE SATISFACTION WITH THESE TWO UNITRON INSTRUMENTS. AMERICAN BRASS, BATTELLE MEMORIAL INSTITUTE, CARNEGIE INSTITUTE, DOW CHEMICAL, E. I. DUPONT, GENERAL ELECTRIC, GENERAL MOTORS, GOODYEAR ATOMIC, I. B. M., MINNEAPOLIS HONEYWELL, M. I. T., MISSOURI SCHOOL OF MINES, MOTOROLA, NATIONAL BUREAU OF STANDARDS, NATIONAL CASH REGISTER, R.C.A., REYNOLDS METALS, UNION CARBIDE & CARBON, UNIV. OF COLORADO, UNIV. OF CINCINNATI, UNIV. OF WASHINGTON, UNIV. OF WISCONSIN, U.S. GOVERNMENT, U.S. STEEL, WESTINGHOUSE ELECTRIC.

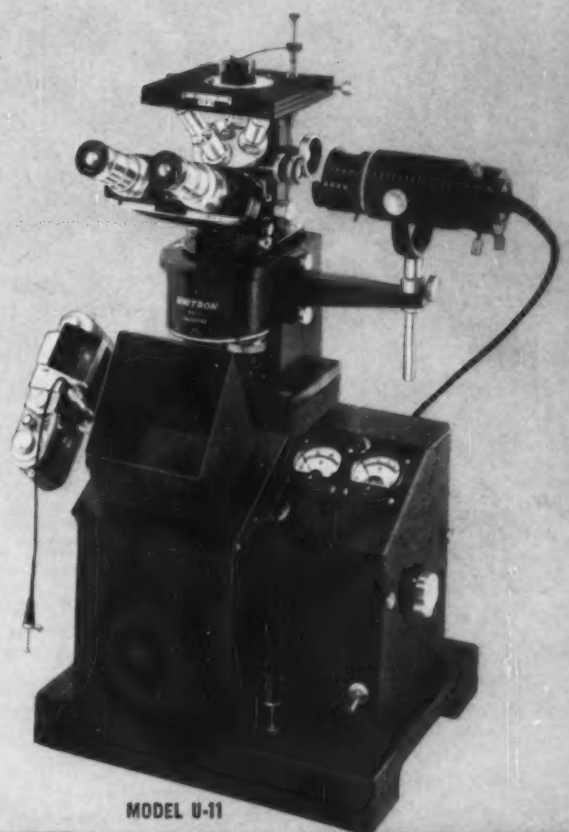
MODEL MEC

UNITRON INVERTED Metallurgical Microscope: This compact unit provides many of the features usually found only in larger metallographs. Standard equipment includes optics for 25–1500X, polarizers, filters, transformer in base, etc. A built-in camera attachment for 35mm. photography is included with the binocular and available for the monocular model. Extra accessories include Polaroid camera attachment, vacuum heating stage and illuminator for transmitted light. Think of the time which your laboratory can save by providing each metallurgist with one of these handy, inexpensive units for use at his desk.

Monocular Model MEC $399 **Binocular Model BMEC $615**

UNITRON METALLOGRAPH and Universal Camera Microscope: A completely self-contained instrument of modern design for visual observation, photography, projection, and measurement of both opaque and transparent specimens; using bright field, dark field, or polarized illumination. Standard equipment includes all optics for 25–2000X, polarizers, filters, 3¼" x 4¼" camera, and many accessories. Also available are camera attachments for Polaroid, 35mm., and motion picture photography; vacuum heating stage for temperatures to 1500° C.; and macro-objectives (5–40X). Even laboratories on a limited budget can enjoy the precision, speed and efficiency possible only with a complete installation of this type.

Monocular Model U-11 $1195 **Binocular Model BU-11 $1379**



MODEL U-11

There is a free 10 day trial offer on any UNITRON Microscope.

Let the instrument prove it's value to you — in your own laboratory — before you decide to purchase.

See for yourself why . . .

THE TREND IS TO UNITRON

Circle 1125 on Page 48-S

UNITRON INSTRUMENT COMPANY • MICROSCOPE SALES DIV.
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Please rush UNITRON'S Microscope Catalog **2-M**

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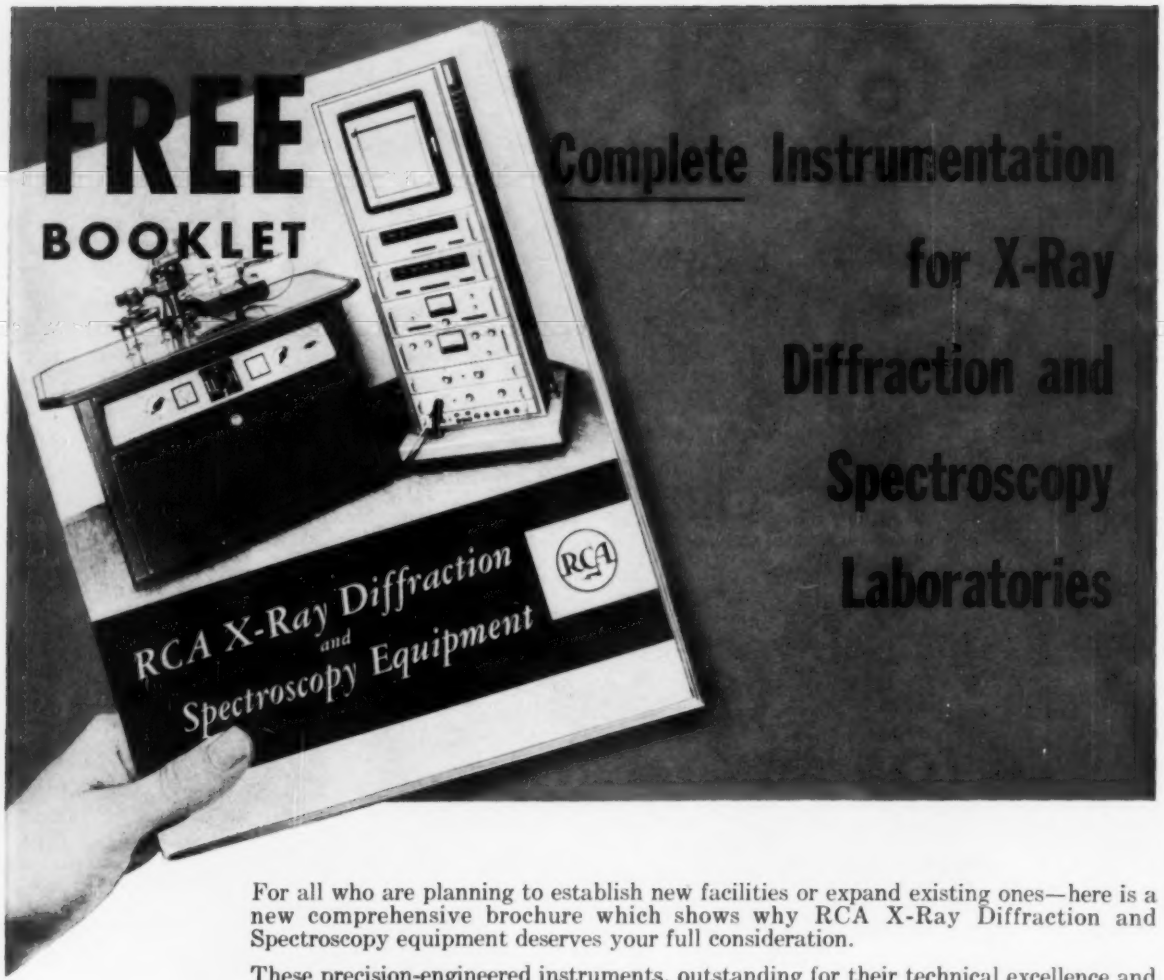

Complete Instrumentation for X-Ray Diffraction and Spectroscopy Laboratories

For all who are planning to establish new facilities or expand existing ones—here is a new comprehensive brochure which shows why RCA X-Ray Diffraction and Spectroscopy equipment deserves your full consideration.

These precision-engineered instruments, outstanding for their technical excellence and performance characteristics, provide unusual versatility for a broad range of X-ray diffraction and spectroscopy studies. An excellent example is the inexpensive RCA kit which permits switching from diffraction to spectroscopy in less than 15 minutes. Fully described in the brochure are:

Console Model Generator—Crystalloflex IV—incorporates constant potential DC power supply plus many other advanced features. An easy-access electronic circuit panel is available for use with this unit.

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An unusually complete line of attachments and accessories for X-ray diffraction and spectroscopy, including a versatile group of cameras, a pole figure goniometer, single crystal layer line and micro-fluorescence attachments, vacuum spectrometer, and digital print-out device.

Contract services on RCA X-Ray Diffraction and Spectroscopy equipment and Electron Microscopes are available through eleven regional offices of the RCA Service Company. A NEW LEASING PLAN now makes it possible to obtain all scientific instruments with no down payment, low monthly terms and a favorable option to buy.

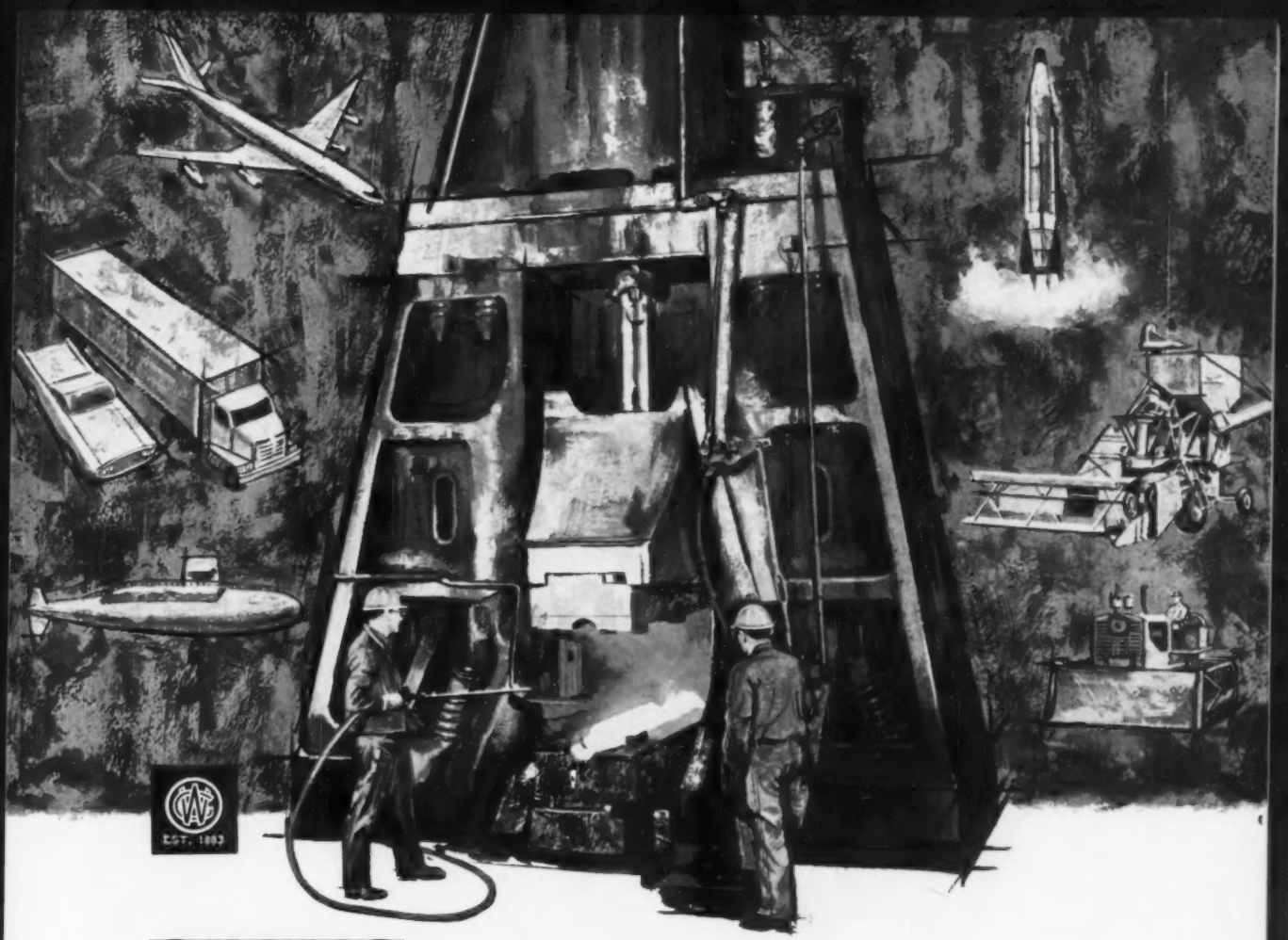
For your free copy of this informative Brochure or for a quotation on your requirements, write to: Radio Corporation of America, Dept. S-72, Building 15-1, Camden, N.J.

RCA®

The Most Trusted Name in Electronics

RADIO CORPORATION OF AMERICA

Circle 1126 on Page 48-B

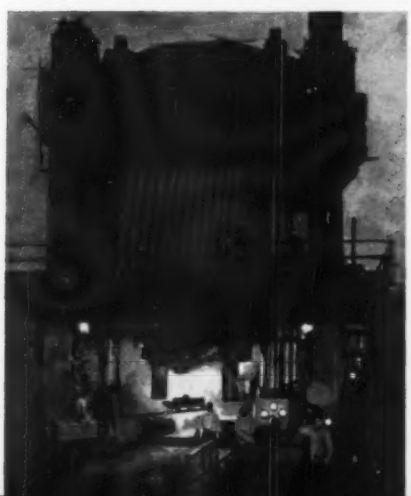


GIVING METAL NEW MUSCLE BY FORGING

. . . a specialty Wyman-Gordon knows best and is best equipped to perform for you

Specify "punishing service" in any environment—land, sea, air or space—and there is no substitute for a forging's endurance. Likewise, specify reliability in your supplier and there is no substitute for experience.

Here Wyman-Gordon has the outstanding record. Our background in hot working all forgeable materials covers more than three-quarters of a century. From it have come most of today's major advances—in forging techniques, metallurgical controls and development of facilities for extending size and complexity of forged parts. This accumulated know-how has done much to make Wyman-Gordon "forging headquarters" for an impressive list of industrial leaders.



Most likely our experience in saving weight, adding strength and reducing machining cost on countless other parts—can do as much for yours. To get expert appraisal, ask to have a forging engineer call while designs are still on the board.

WYMAN-GORDON

FORGINGS

of Aluminum Magnesium Steel Titanium . . . and Beryllium Molybdenum Columbium and other uncommon materials

HARVEY ILLINOIS — WORCESTER MASSACHUSETTS — DETROIT MICHIGAN

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Circle 1127 on Page 48-B

STST*

*Superior Tool Steel Tubing

ODDS: 1000 TO 1 TO CUT COSTS, IMPROVE PERFORMANCE IN 1001 DIFFERENT APPLICATIONS

Superior tool steel tubing is an excellent material for tools, but equally good for 1001 other applications. Odds are that it will cut costs and improve performance wherever it is used. Type E-52100, an oil hardening grade of high-carbon and chromium alloy steel, has been widely used for such diverse applications as thread guides on hosiery knitting machines, nylon yarn guides, ball bearing races, nozzles for blast cleaning equipment, gear and pinion parts, dental instruments and extrusion mandrels. Type E-1095, a high-carbon steel tubing, is serving as applicators for jewelers' oilers, leather and paper punches, and surgical instruments.

Perhaps you have an application that can benefit from high strength and hardness, good wear resistance, abrasion resistance, shock resistance, and notch toughness. In that case, consider Superior tool steel tubing before you go any farther. It could give you a better product at a lower cost. Send for Data Memorandum #14, a handy guide to your thinking. Superior Tube Company, 2008 Germantown Ave., Norristown, Pa.

Steel

Superior Tube

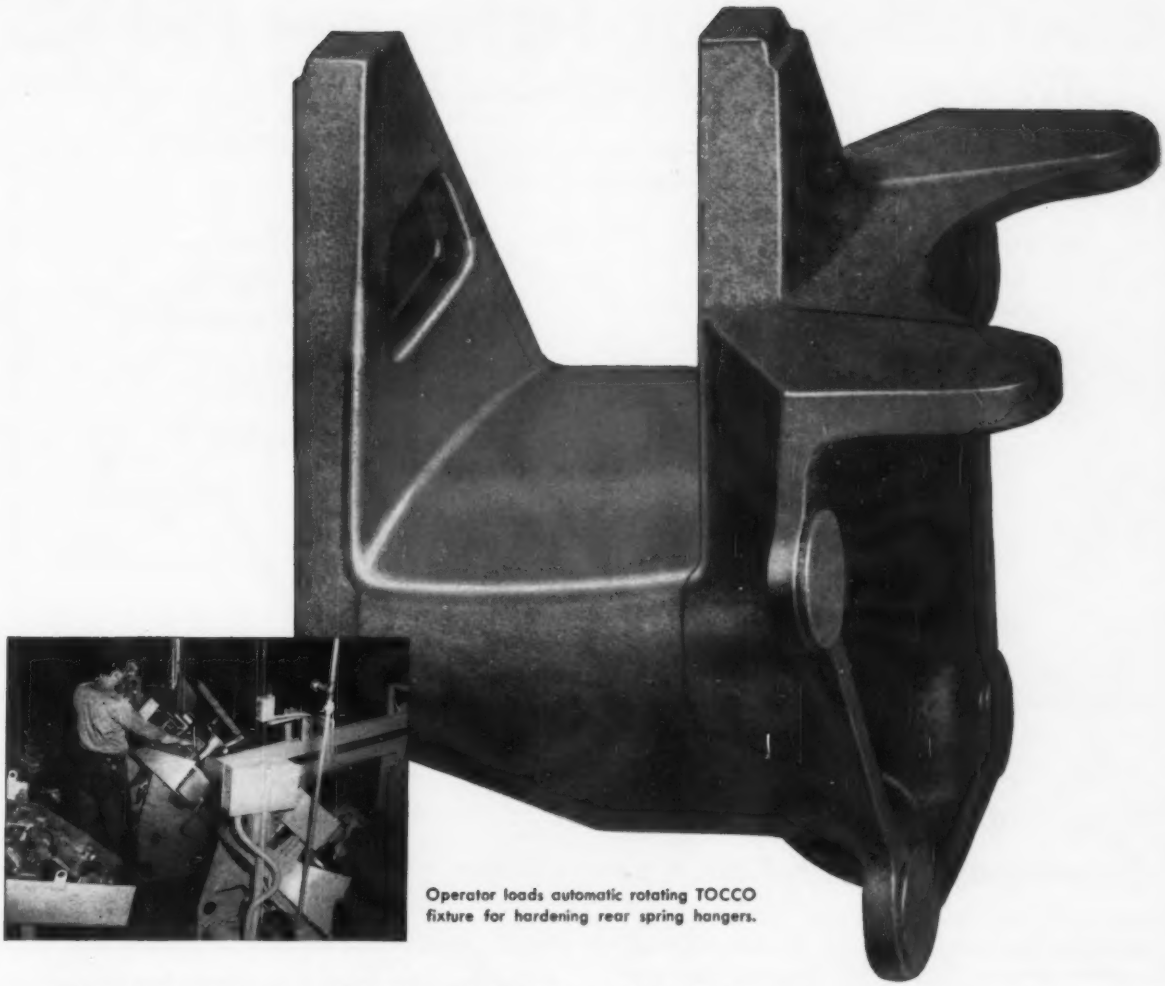
The big name in small tubing

NORRISTOWN, PA.

All analyses .010 in. to ⅜ in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST

Circle 1128 on Page 48-B



Operator loads automatic rotating TOCCO fixture for hardening rear spring hangers.

The job they said "couldn't be done"

now being hardened—1 every minute

with TOCCO Induction Heating*

This unusually shaped part is a rear spring hanger used in the spring suspension system of a major truck manufacturer. The hardness pattern covers the "flat" section, which actually isn't flat but blends two widely varying radii, and the sides or "ears" a portion of which must be hardened to the same depth—.060" to .090". Nine of these irregularly shaped castings are loaded in a rotating fixture and scanned progressively by a TOCCO inductor block at the rate of one per minute. An air gap of .060" is maintained between the inductor and the part—quite a tricky achievement since the spring hangers are unmachined castings with normal foundry tolerances of ±.045".

This job is typical of many where TOCCO engineers have worked out a satisfactory and reliable production setup for a supposedly impossible heating job. If you have a difficult heating job—hardening, brazing, soldering or heating for forming or forging it will pay you to consult TOCCO—without obligation, of course.

THE OHIO CRANKSHAFT COMPANY

Mail Coupon Today— NEW FREE Bulletin

The Ohio Crankshaft Co. • Dept. R-3, Cleveland 5, Ohio

Please send copy of "Typical Results of TOCCO Induction Hardening and Heat Treating"

Name_____

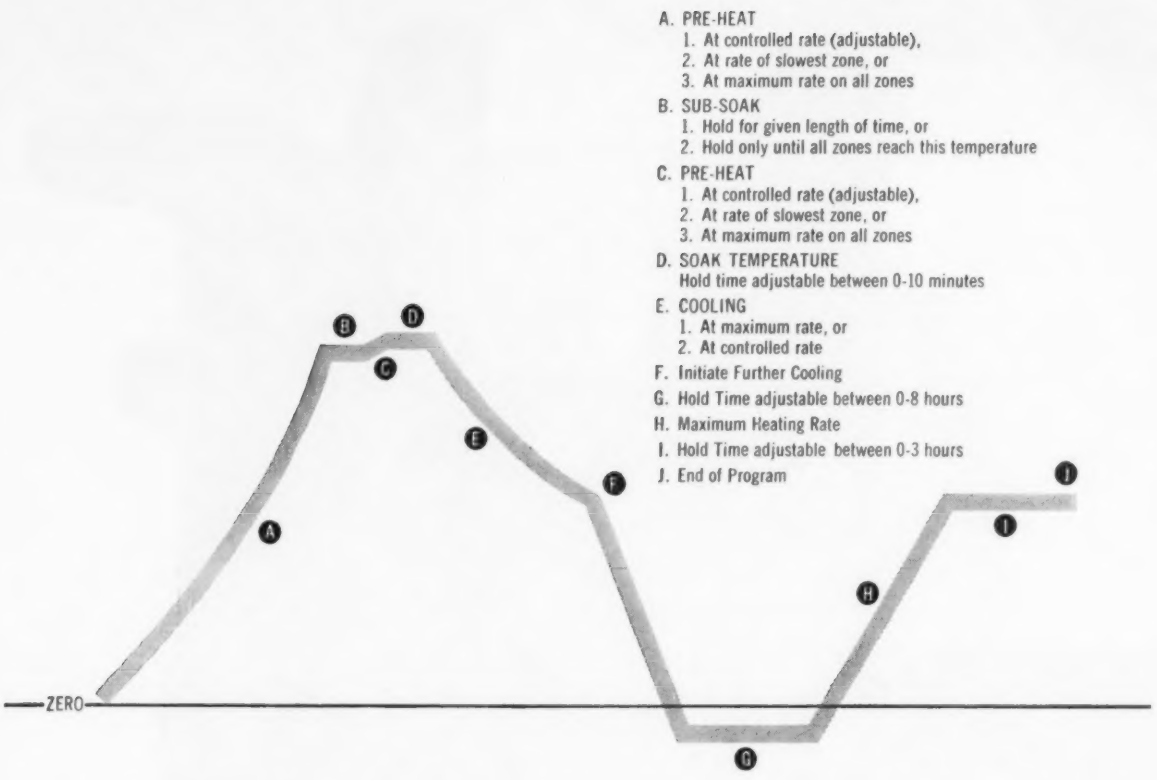
Position_____

Company_____

Address_____

City_____ Zone____ State_____

Circle 1129 on Page 48-B



When temperature uniformity is a must... reproduce your heat-treating cycles with L&N's new master-slave program control

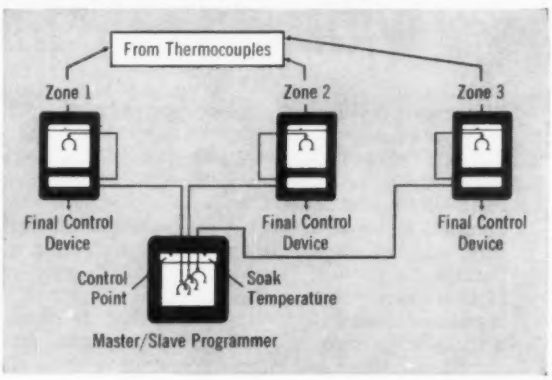
Designed for applications where temperature uniformity is of prime importance, L&N's new master-slave program control system has the flexibility to take your product—with minimum temperature gradient—through various heating and cooling cycles. It is currently being used in brazing stainless steel honeycomb panels for supersonic aircraft and missiles.

You can use this system on either batch or continuous furnaces . . . can control from either work or furnace temperatures. Heating cycles may be at a fixed rate, or at the rate determined by the slowest or fastest heating zone. As many as twenty-four zones may be automatically controlled by one master-slave programmer.

This master-slave system is available with 3-action P.A.T. control for fuel-fired furnaces; with 3-action C.A.T. control for continuous, stepless regulation of input to electric heaters or blankets; or with D.A.T. control for either electric or fuel-fired furnaces.

The system includes Speedomax® H controllers with appropriate couples and control devices for each zone; and a master-slave programmer for automatically and continuously adjusting control-point for each zone.

If your process can benefit from precisely controlled heating and cooling, you may be surprised to learn how large a return you can get by modernizing with this quality instrumentation. For details, call your nearest L&N office, or write us at 4927 Stenton Ave., Phila. 44, Pa. Ask for Process Data Sheet 660(2).



LEEDS & NORTHRUP
Instruments — Automatic Controls • Furnaces

Pioneers in Precision

Circle 1130 on Page 48-B

High electrical conductivity PLUS machining savings like this — with Anaconda Leaded Copper-126

MACHINING COST COMPARISON

	LEADED COPPER-126 (Electrical conductivity 98% I.A.C.S.†) (Relative machinability, 80)	ELECTROLYTIC T.P. COPPER (Electrical conductivity 101% I.A.C.S.) (Relative machinability, 20)
CLIP ASSEMBLY (including leaves)	Machine fill* Drill Tap hrs per 100 pcs. **4.310**	Hand fill Drill Tap hrs per 100 pcs. **10.838**
BLOCK	Cut-off Slot Grind hrs per 100 pcs. **2.641**	Cut-off Slot Grind hrs per 100 pcs. **4.622**
TOTAL	hrs per 100 pcs. **6.951**	hrs per 100 pcs. **15.460**

*Parts are assembled, pin drilled, and pinned on a semiautomatic machine. Machine does not operate satisfactorily with Electrolytic T.P. Copper.

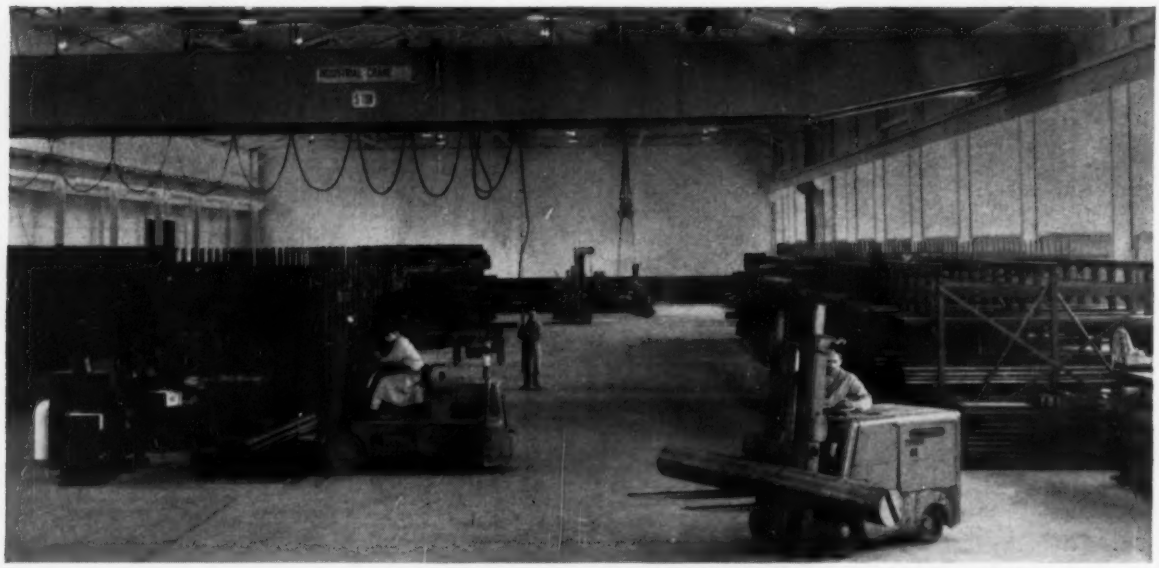
†Average for annealed metal—slightly lower in hard tempers

55% SAVING in production time PLUS savings in longer tool life—cutters, 400%—drills, 33%—taps, 33%.

Scores of electrical components made by Barkelew Electric Mfg. Co., Middletown, Ohio, specialists in the manufacture and development of high-capacity switching equipment for over 50 years, require high electrical conductivity in service and considerable machining in manufacture. The figures above for a clip assembly typify the savings made possible by the use of Anaconda's high conductivity Leaded Copper-126. Other applications include pieces machined from bar stock as large as 4½" x 2". Leaded Copper-126 is available in standard mill forms. For more information, see your Anaconda representative – or write: Anaconda American Brass Co., Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont. 6053L

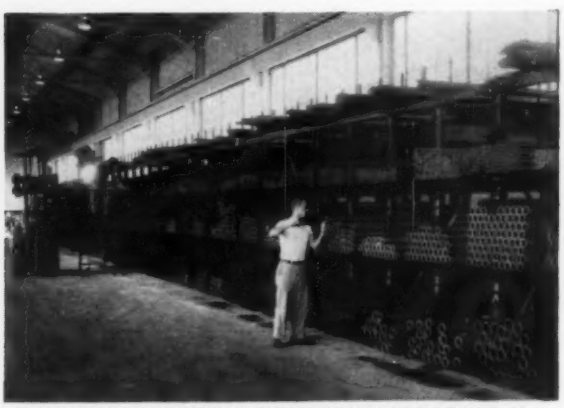
ANACONDA®
ELECTRICAL COPPERS
Anaconda American Brass Company

How Timken® Steel from helps you keep production



EXPERT TECHNICAL SERVICE. Your Steel Service Center representatives are experienced, trained to help on your steel applications. And when you buy Timken steel, help is also yours from Timken Company experts—specialists in fine alloy steel for over 40 years. The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable: "TIMROSCO". Makers of Tapered Roller Bearings, Fine Alloy Steel and Removable Rock Bits.

PROMPT DELIVERY. You get fast dependable delivery of steel products from your Steel Service Center. It helps you keep production on schedule, meet emergencies. Steel Service Centers are equipped to prepare steel to size required, ready for use, cutting your processing cost. And when it's Timken® seamless steel tubing, graphitic tool steels, alloy steel bars or billets, you can be sure it's the finest steel made.



CUTS YOUR INVENTORY COST, RELEASES SPACE. Your Steel Service Center stocks a wide variety of steel products. Result—you can reduce your inventory costs, put inventory capital to work elsewhere. And you can release storage space for more productive work.

TIMKEN® *Fine Alloy* STEEL

your Steel Service Center schedules, cut costs

FOR FAST, ABLE SERVICE ON TIMKEN® SEAMLESS STEEL TUBING, GRAPHITIC TOOL STEELS AND ALLOY STEEL BARS CALL THESE STEEL SERVICE CENTERS

LOCATION	STEEL SERVICE CENTER
ALABAMA	
Birmingham	O'Neal Steel, Inc.*†
ARIZONA	
Phoenix	Earle M. Jorgensen Co.*†•
CALIFORNIA	
Los Angeles	Allen-Fry Steel Company*
	Baker Steel & Tube Co. •
	Coulter Steel & Forge Co.*†
	Earle M. Jorgensen Co.*†
	Kilsby Tube Supply, Division of Republic Supply Co. of Calif.•
	Joseph T. Ryerson & Son, Inc.*•
	Service Steel Division Van Pelt Corp.•
	Tube Distributors, California, Inc. •
	Tubesales•
Oakland	Coulter Steel & Forge Company (Emeryville)*†
	Earle M. Jorgensen Co.*†
	Joseph T. Ryerson & Son, Inc.*•
San Francisco	Baker Steel & Tube Co.•
	Earle M. Jorgensen Co.*†
	A. Milne & Co., Inc. (Burlingame)†
COLORADO	
Denver	Earle M. Jorgensen Co.*†•
CONNECTICUT	
Windsor	SAE Steels, Inc.*
GEORGIA	
Atlanta	A. Milne & Co., Inc.†
	O'Neal Steel, Inc.*†
HAWAII	
Honolulu	Earle M. Jorgensen Co.*†•
ILLINOIS	
Chicago	Chicago Tube and Iron Co.•
	Hy-Alloy Steels Co.*•
	A. Milne & Co., Inc. (Melrose Park)†
	The Peninsular Steel Co.†
	Joseph T. Ryerson & Son, Inc.*•
	Service Steel Division Van Pelt Corp.•
INDIANA	
Ft. Wayne	Tubular Sales•
Indianapolis	The Peninsular Steel Co.†
KANSAS	
Wichita	Earle M. Jorgensen Co.*†•
LOUISIANA	
New Orleans	Earle M. Jorgensen Co.*†•
MASSACHUSETTS	
Boston	A. Milne & Co., Inc.†
	Joseph T. Ryerson & Son, Inc. (Allston)*•
MICHIGAN	
Detroit	Alloy Steels, Incorporated†
	A. Milne & Co., Inc.†
	The Peninsular Steel Co.†
	Joseph T. Ryerson & Son, Inc. •
	Service Steel Division Van Pelt Corp.•
	Tubular Sales•
Grand Rapids	The Peninsular Steel Co.†
MINNESOTA	
St. Paul	Paper, Calmenson & Company*
MISSISSIPPI	
Jackson	O'Neal Steel, Inc.*†
MISSOURI	
St. Louis	Ford Steel Company†
	Joseph T. Ryerson & Son, Inc.*•
NEW JERSEY	
Elizabeth	A. B. Murray Co., Inc.•
Englewood	Tubesales•
Jersey City	Joseph T. Ryerson & Son, Inc.*•
Kenilworth	A. Milne & Co., Inc.†
Linden	Bowsteel Distributors Corporation*
Newark	Faitoute Iron & Steel Company, Inc.*
NEW YORK	
Buffalo	The Peninsular Steel Co. (Tonawanda)†
	Joseph T. Ryerson & Son, Inc.*•
	Service Steel Division Van Pelt Corp.•
Garden City (L.I.)	Tube Distributors Co., Inc.•
New York	A. Milne & Co., Inc.†
NORTH CAROLINA	
Charlotte	Joseph T. Ryerson & Son, Inc. •
OHIO	
Akron	The Peninsular Steel Co.†
Cincinnati	Ford Steel Company†
	Joseph T. Ryerson & Son, Inc. •
	SAE Steels, Inc.*
	Service Steel Division Van Pelt Corp.•
Cleveland	A. Milne & Co., Inc.†
	The Peninsular Steel Co. (Bedford Heights)†
	Joseph T. Ryerson & Son, Inc.*•
	SAE Steels, Inc.*
Dayton	Alloy Steels, Incorporated†
	A. Milne & Co., Inc.†
	The Peninsular Steel Co.†
Toledo	The Peninsular Steel Co.†
OKLAHOMA	
Tulsa	Earle M. Jorgensen Co.*†•
OREGON	
Portland	Pacific Machinery and Tool Steel Co.†
PENNSYLVANIA	
Bristol	A. B. Murray Co., Inc.•
Butler	Keystone Pipe & Supply Co.•
Carnegie	A. Milne & Co., Inc.†
	Joseph T. Ryerson & Son, Inc.*•
McKeesport	A. B. Murray Co., Inc.•
Philadelphia	Capitol Pipe & Steel Products, Inc.•
	A. Milne & Co., Inc.†
	Joseph T. Ryerson & Son, Inc.*•
TENNESSEE	
Chattanooga	O'Neal Steel, Inc.*†
TEXAS	
Dallas	Earle M. Jorgensen Co.*†•
	Joseph T. Ryerson & Son, Inc.*•
Houston	Earle M. Jorgensen Co.*†•
	Peden Iron & Steel Co.•
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UTAH	
Salt Lake City	Coulter Steel & Forge Company*†
WASHINGTON	
Seattle	Coulter Steel & Forge Company*†
	Earle M. Jorgensen Co.*†
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Spokane	Joseph T. Ryerson & Son, Inc.*•
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CANADA	
London, Ontario	Vanadium-Alloys Steel Canada, Limited†
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	Vanadium-Alloys Steel Canada, Limited†
Toronto, Ontario	Drummond, McCall & Co., Limited•
	Vanadium-Alloys Steel Canada, Limited†

* Alloy Steel Bars and Billets † Graphitic Tool Steels • Seamless Steel Tubing

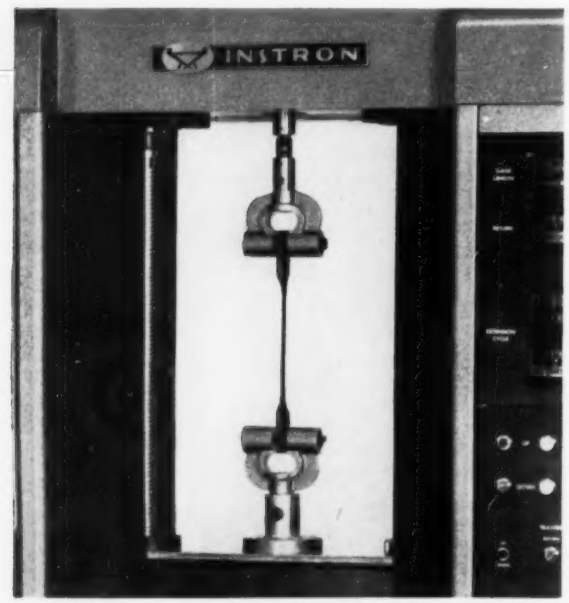
Circle 1132 on Page 48-B

$$ST_0/RTa_T = \int_{-\infty}^{\infty} M(\tau)\tau(1-e^{-\gamma/R\tau a_T})\,d\ln\tau$$

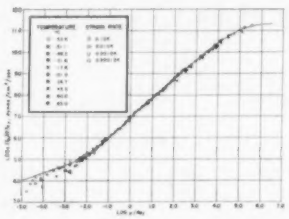
.....OR HOW TO PREDICT VISCOELASTIC BEHAVIOR FROM SIMPLE STRESS-STRAIN DATA

The above formula, recently developed with an assist from Instron, enables rheologists to predict, with accuracy, the complex linear viscoelastic properties of certain polymers from simple stress-strain data. For example, it is possible to calculate stress-relaxation modulus from a simple tension test.

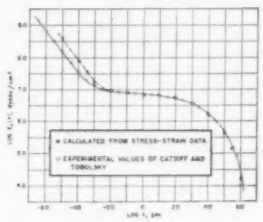
The equation itself was none of our doing, of course. (For details on how the equation was developed, see below.) But we can point with pride to the fact that the universal tester which furnished the stress-strain criteria used in the study of the applicability of the new formula to polymeric material bears the Instron name.



The Instron's servo-controlled testing speed was extremely useful in the test. The constant crosshead speed imposed constant strain rate in the sample for elongations up to 150%. Unique extension-recording system of the Instron made it possible to measure strain accurately without extensometers.



Stress-strain data reduced to unit strain rate at 298°K.

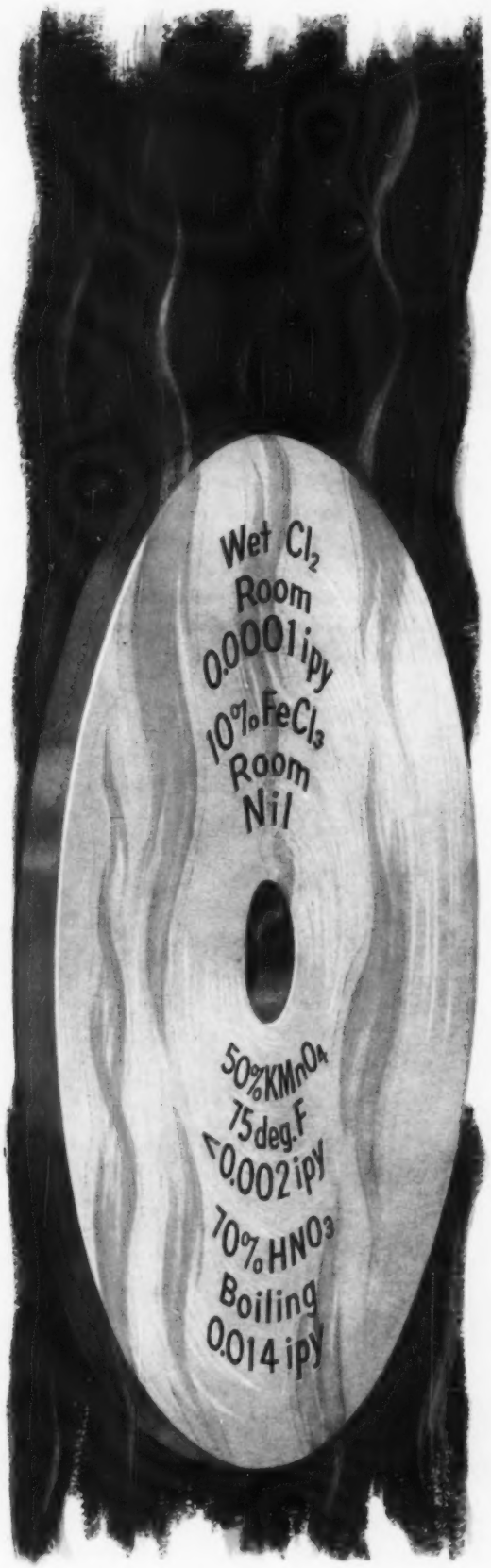


Stress-relaxation modulus derived from stress-strain data compared with experimental data of Catsiff and Tobolsky.

When accuracy is paramount, it is the Instron that is often chosen to provide the standards . . . proof that you can do more with an Instron. If you have any problem at all related to materials testing, write for the Instron catalogue. Also available: our ever-growing library of articles on advanced testing techniques, covering many fields. Yours for the asking — just mention your particular field of interest.

$$ST_0/RTa_T = \int_{-\infty}^{\infty} M(\tau)\tau(1-e^{-\gamma/R\tau a_T})\,d\ln\tau$$

How the formula was used: Samples of synthetic, non-crossed linked rubber were tested at 10 temperatures between −54° and 85°C, and at constant strain rates between 0.014 and 0.104 x 10^{-3} sec^{-1} on the Instron Universal Tester. Stress-strain data were reduced mathematically to unit strain rate to yield a single curve for each temperature. Curves were then superposed to determine temperature dependence of viscosity, then all data up to 100% elongation were reduced to a single stress-strain curve accurately predicting viscoelastic behavior over nine decades of reduced time. It was shown that stress-relaxation modulus could be calculated satisfactorily from the reduced stress-strain curve.



Corrosion from Oxidizing Chemicals?

...Test **HAYNES** Alloys

Even in such violently corrosive oxidizing agents as ferric chloride—at concentrations boosted to 40 per cent and temperatures as high as 140 deg. F.—HASTELLOY alloy C figuratively snaps its fingers. At room temperature, its reaction is nil!

Alloy C and other HAYNES alloys resist most of the common oxidizing chemicals. Alloy C also resists strongly oxidizing salts such as cupric chloride, ferric and cupric sulphate, and chromates and nitrates in sulphuric and hydrochloric acids.

If oxidizing chemicals are a problem, you'll almost surely find the remedy among HAYNES alloys. There are nine HAYNES alloys developed over a 30 year span of intensive concentration on corrosion problems and the metals that best resist them.

Send for test samples . . . by sending us a letter outlining your corrosion problem. We will send you test samples of the HAYNES alloy best suited to resist it. Be sure to ask for a booklet on HASTELLOY alloys. Address us at 270 Park Avenue, New York 17, N. Y.

HAYNES
ALLOYS
HAYNES STELLITE COMPANY

Division of
Union Carbide Corporation
Kokomo, Indiana

UNION CARBIDE

"Haynes," "Hastelloy," and "Union Carbide" are registered trade marks of Union Carbide Corporation.

Circle 1134 on Page 48-S

REPUBLIC HIGH-PERFORMANCE METALS FOR THE HU2K

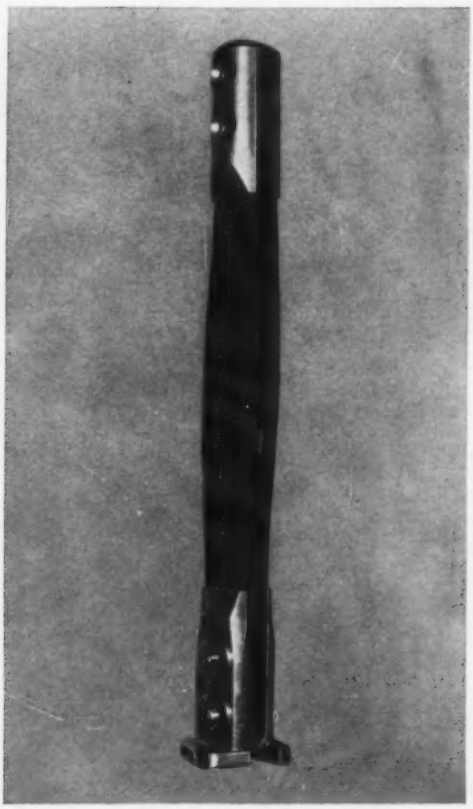
Scheduled for fleet delivery in 1961, the all-weather Kaman HU2K "SEASPRITE" was developed to meet *high-performance* requirements of the U. S. Navy. Working closely with Kaman design engineers, Republic Steel is supplying light gage titanium and stainless steel for the HU2K.

Selected for its resistance to corrosion and abrasion, stainless is used in leading edges of the rotor blades. The titanium—Type RS140—is used in 1½″ x 18″ strips. Assembled in bundles of 88, these strips are machined into retention straps that are a vital component in the rotor system.

May we help you utilize *high-performance* metals in your project? Republic is the nation's largest producer of alloy and stainless steels, and a major producer of titanium. Republic has the most *extensive vacuum-melting facilities* ever assembled. For complete details, contact your Republic representative or mail the coupon.

REPUBLIC VACUUM-MELTED METALS are produced in 18- to 32-inch diameter ingots weighing from 4,000 to 20,000 pounds. Vacuum-melted super alloy steels, constructional alloy steels, high strength alloy steels, bearing steels, stainless steels, titanium, and special carbon steels are available from Republic in plates, billets, bars, sheets, strip, and wire. Mail coupon for complete information.

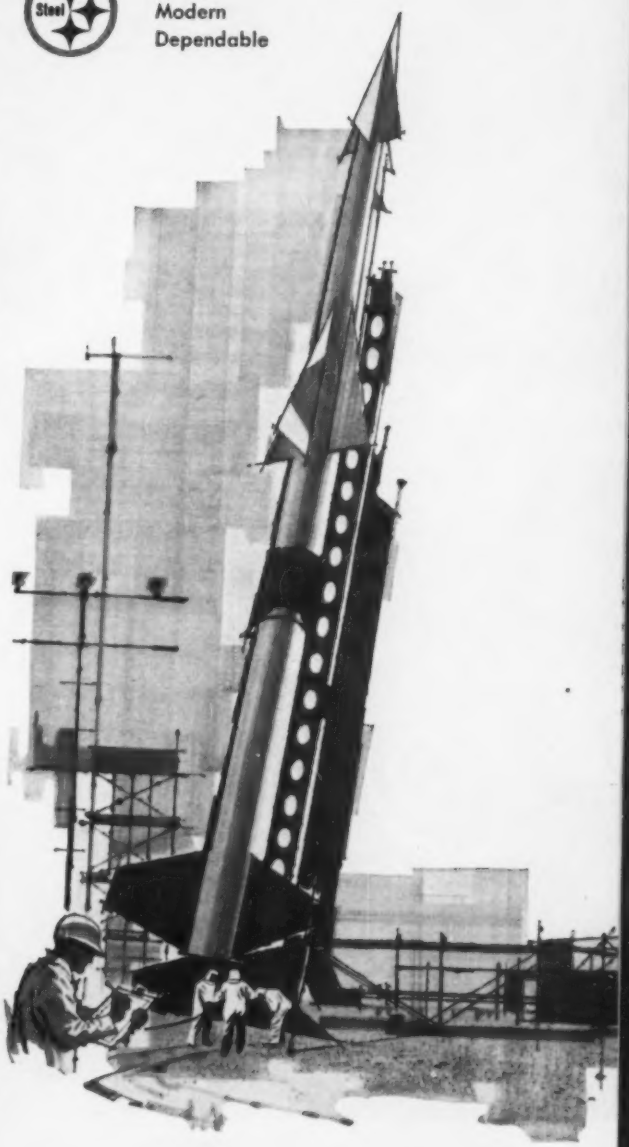
3-DIMENSIONAL METALLURGICAL TEAMS: Republic's mill, field, and laboratory metallurgists and machining experts help you select and apply the metal best suited to requirements. Mail coupon for details on this confidential, obligation-free service.



BUNDLED TITANIUM RETENTION STRAPS are designed to work through a torsion angle of ±13°. Each strap provides a minimum tensile strength of 155,000 psi. The HU2K "SEASPRITE" is manufactured by the Kaman Aircraft Corporation, Bloomfield, Connecticut.

Circle 1135 on Page 48-B

Strong
Modern
Dependable



REPUBLIC STEEL

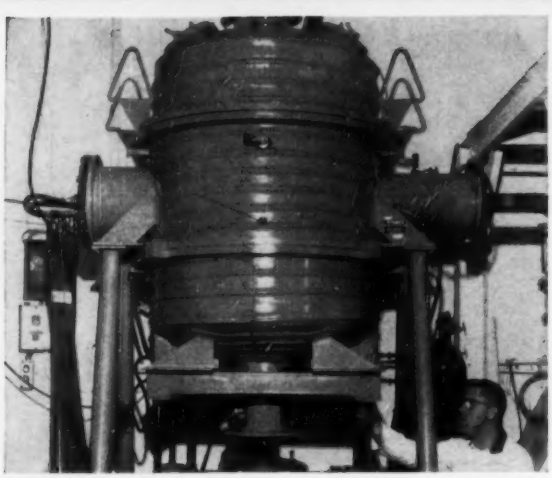
Where Steels are Made
to Meet the Challenge of Acceleration

REPUBLIC STEEL CORPORATION
DEPT. MP -9656-A
1441 REPUBLIC BUILDING • CLEVELAND 1, OHIO

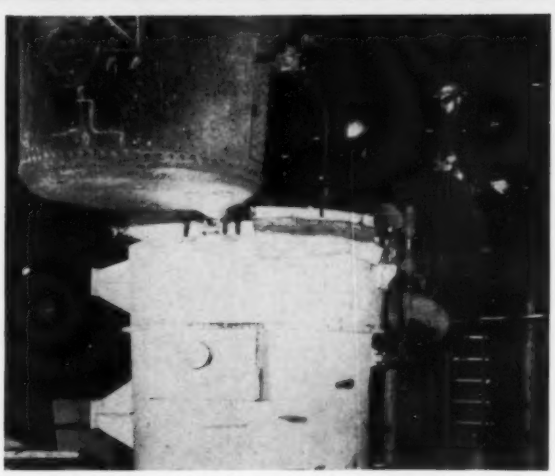
Please send more information on:
☐ Republic Titanium
☐ Stainless Steel ☐ Vacuum-Melted Metals
Have a metallurgist call:
☐ Republic Titanium
☐ Stainless Steel ☐ Vacuum-Melted Metals

Name_____ Title_____
Company_____
Address_____
City_____ Zone____ State_____

One of the largest cold-wall vacuum heat treating furnaces ever built, capable of operations at temperatures above 2000°F. was recently installed by Stokes. The huge furnace will be used in brazing and heat treating the high alloy steels used in the production of missile components. It has a vacuum chamber 12 feet long and 9 feet in diameter.



Uranium melting on a production basis is accomplished by this Stokes induction melting furnace at Atomics International. Designed for safety and convenience, the furnace is serviced from the top and features a removable bottom section to facilitate handling of cast materials.



First acid open hearth, vacuum stream ladle degassed, air-pouring of multiple ingots in the U. S. took place at Ohio Steel Foundry in Stokes equipment. Results showed low hydrogen values, good inclusion reduction and excellent physical property improvement.

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a Stokes specialty in vacuum metallurgy

Staffed and equipped to undertake projects which contain unusual problems, Stokes offers the most comprehensive background of vacuum metallurgical experience and know-how available today. Stokes is geared to tackle even the most complex assignments . . . assignments for which the application of high vacuum is the only practical solution.

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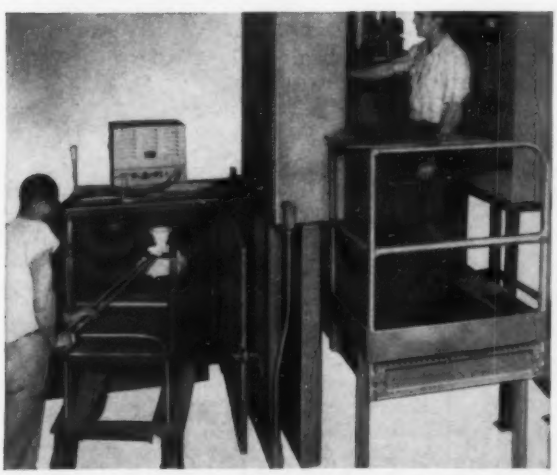
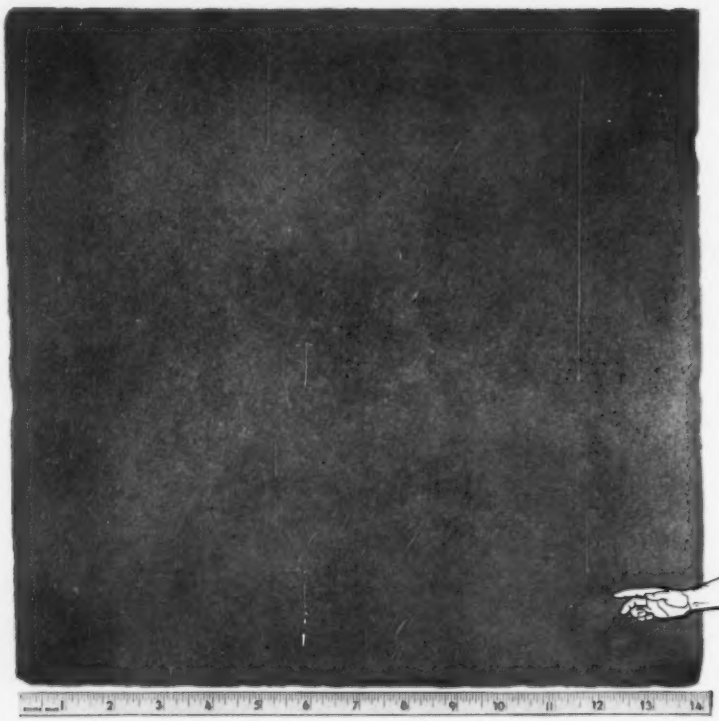


At Misco Precision Casting Co., semi-continuous vacuum melting and casting are being accomplished in two Stokes induction furnaces. Successive charges of the metal are introduced into the vacuum chamber from the outside, loaded into the crucible, melted, poured, and the cast pieces (in their molds) removed from the chamber . . . without breaking the vacuum.

Vacuum equipment capable of brazing panels in excess of 50 sq. ft. is being used in pilot operation by Grumman Aircraft Engineering Corporation to fabricate structures for the "Eagle" air-to-air missile. The Stokes equipment employs a new procedure which eliminates expensive and time-consuming welded "envelopes" to enclose the work. And high vacuum eliminates the need for costly inert gas.

Circle 1136 on Page 48-B

HIDDEN VALUES in Finkl Products



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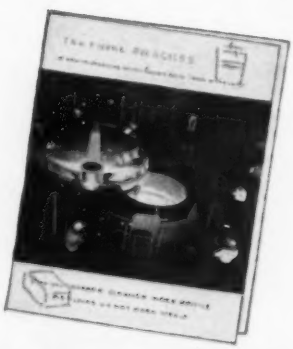

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Circle 1137 on Page 48-B

Metal Progress

Vol. 79, No. 3 March 1961

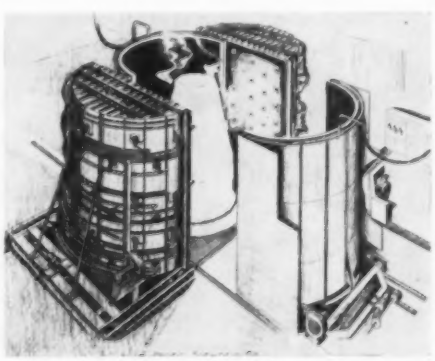
NEWS • NEWS • NEWS • NEWS • NEWS • NEWS • NEWS • NEWS • NEWS •

Technical NEWS in Brief

New Brazing Furnace for Large Rocket Engines

One of the important projects in our efforts to conquer space is the development of rocket engines to generate more than a million pounds of thrust. In this area, furnace brazing has proved to be a reliable method for fabrication of thrust chambers of rocket engines. Tubes are assembled (see p. 84 for typical thrust chamber) and the chamber is enclosed in an air-tight retort which is purged with an inert gas. Brazing is done in a controlled non-oxidizing atmosphere. The furnace technique, which has been used to produce reliable chambers for current engines, also offers advantages in fabricating extremely large chambers where new high-strength stainless steel tubes do not lend themselves to hand brazing operations. New brazing techniques, developed by Rocketdyne Div. of North American Aviation, Inc., permit fabrication of a wide range of thrust chamber sizes in which a greater variety of high-strength steels can be used.

The type of furnace which has been employed has been the conventional bell arrangement. When Rocketdyne started work to develop production facilities for the F-1 rocket engine, which will generate up to 1,500,000 lb. of thrust, the large size of the chamber made it desirable to consider a new type of brazing furnace (shown schematically at right). Rather than employing an enlarged bell furnace, which would have required a tall structure to permit it to be lowered and raised, the new furnace, (engineered and constructed by Pacific Scientific Co., Los Angeles) uses two gas heating sections that move on rails to surround the retort containing the unbrazed thrust chamber. Temperatures in the range of about 2300° F. are required. When the brazing operation is completed, the furnace sections are moved away from the hot retort and two sections equipped for water cooling are positioned so that they surround the retort to speed cooling. Construction has been completed



Brazing Furnace for Large Thrust Chamber
Heating and Cooling Sections Move to Surround Retort

on the new furnace and trial runs are now in progress. *Metal Progress* will present a complete story (prepared by Rocketdyne engineers) when production information is available on fabrication of the F-1 engine.

Thrust of the F-1 engine is the highest of any of the engines now being developed in the U. S. The single-chamber rocket engine used in clusters providing from 6 to 9 million lb. of thrust could put a 400,000-lb. load in a low-altitude earth orbit. Such a vehicle also could be used for a manned lunar landing and return to earth. Rocketdyne began research toward an engine in the million-pound thrust class several years before winning an N.A.S.A. contract to produce the F-1 engine.

Engine Blocks and Heads Cast by Semi-Permanent Mold Process

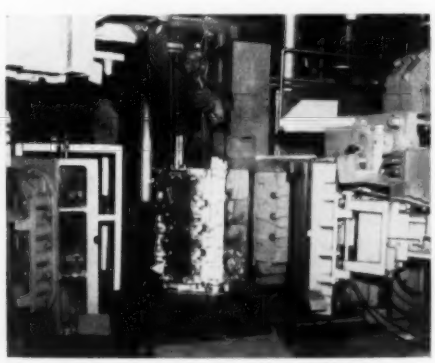
Semi-permanent molding is being used to make aluminum cylinder blocks and heads for the 1961 Buick Special, Oldsmobile F-85 and Pontiac Tempest at the rate of 1300 castings per day. Although die and low-pressure casting (see *Metal Progress*, February 1961, p. 84) have been employed successfully to produce engine components, neither technique is feasible for the V-8, water cooled blocks and heads for the three new compacts.

Produced by General Motors' Central Foundry Div. in Defiance, Ohio, each of the castings requires six dry sand cores (a special urea sand mix with good collapsibility) to form the intricate crankcase and water jacket passages. Sand cores are also used to form the water jacket, header and intake and exhaust ports of the cylinder head. All cores are made in conventional mixing and blowing equipment.

The alloy (356) is melted in four gas-fired reverberatory furnaces. The metal is fluxed, analyzed and then tapped directly into 1000-lb. delivery ladles and transported to gas-fired holding pots on the molding platforms. Gas content is checked and controlled in the holding pot. Some gas is desired since it breaks up the continuity of shrinkage and thus cuts the number of castings that are rejected in subsequent pressure tests.

Blocks are cast vertically in hydraulically operated machines. All sections of the metal molds are water cooled, temperatures being recorded on a master recorder. Precast gray iron cylinder liners, grooved to insure a good bond with the aluminum, are positioned with retractable mandrels.

After the casting is removed from the mold, it is cooled for about 2 hr., core sand is shaken out and fins are taken off automatically. Block castings are shot-blasted in the crankcase area to remove residual sand. Machining and further cleaning follow and finally an aging treatment for 5 hr. at 400° F. to relieve stresses and stabilize the parts.



ALUMINUM BLOCK CASTING FOR V-8 ENGINE
Semi-Permanent Mold Process Makes
1300 Castings Per Day

Stainless Steel Used in Auto Mufflers

Exhaust mufflers containing more than 50% stainless steel are being produced for the Ford Motor Co. The mufflers, used in the dual exhaust system of the 1961 Thunderbird, weigh 13 lb. each. Seven pounds of stainless steel, an alloy known as MF-1 containing 11% chromium and introduced by Allegheny Ludlum, are used in the inner shell, one of the baffles and both of the muffler heads. The inner shell and baffle are 0.036 gage; heads are 0.048 gage.

The new muffler is expected to last at least three times longer than standard mufflers. Metallurgists at Allegheny Ludlum estimate that MF-1 is five to six times more resistant to corrosion than aluminized steel and 15 to 18 times more resistant than mild steel.

Two-Pass Welding of Thick Aluminum Plates

By employing a technique which will weld heavy aluminum plate in two passes instead of multiple passes as is now normally required, arc time and the amount of shielding gas used can be reduced by about 50%. Using modified automatic MIG welding equipment and 1/16-in. filler wire, engineers at the welding engineering branch of Kaiser Aluminum & Chemical Corp. in Oakland, Calif., have accomplished two-pass welding with full penetration and good weld quality in 5083 alloy plate 2 in. thick. They report that some changes in equipment and attention to joint design are required for successful two-pass welding.

One of the changes is that high current and voltage are employed. Kaiser engineers have worked with currents up to 450 amp. at 40 v. on an experimental basis but state that 400 amp. appears to be the practical limit for this size of filler wire in shop production. This compares with 300 amp. and 30 v. commonly used for multi-pass MIG welding with 1/16-in. filler wire and an argon shield. Deep penetration is obtained by increasing the wire feed rate until most of the arc is below the level of the plate surface. This does not decrease the arc

length but instead results in deep penetration.

With plates up to 1¼ in. thick it is possible to use square butt designs; beveled edges are recommended in heavier sections. Butt and fillet welds can be made, but the large molten weld pool means that only flat or down-hand welding can be employed.

Mechanical properties of two-pass welds have proved adequate to meet the strength requirements specified in the A.S.M.E. pressure vessel code. In addition, tests show that the welds also meet the side-bend requirements of the code which call for a 180° bend around a 2T radius without showing defects. Kaiser engineers attribute good weld quality to the formation of a large weld pool which remains molten for a longer time, thus allowing gases and oxide particles to escape. Because less metal and fewer weld passes are needed, the chances for contamination are reduced.

Progress in Nonmetallic Materials

Molybdenum disulphide filled with nylon is being used as a bearing material on new boat trailers made by Parish Pressed Steel Div. of the Dana Corp., Reading, Pa. The material is formed (by injection molding) into split ring bearings which snap into place inside steel tubes that serve as the hubs for inflated balloon rollers. In service the bearings are subjected to severe conditions of corrosion from salt and fresh water immersion, impact loading during transport and deformation during prolonged loading when the boat is on the trailer.

Tests with the nylon-molybdenum disulphide material, called Nylatron GS by Polymer Corp., Reading, Pa., indicate that it retains the corrosion resistance of nylon but eliminates the problems of water absorption and cold flow. Bearing qualities are also retained even though flakes of rust work between the bearing and axle.

Metal Powder Compacted in Big Gun Barrel

Tungsten "pots" which are machined into exhaust nozzles for rocket engines of solid-fuel missiles are being made by compacting metal powder in a hydrostatic press. Pressing is performed in 50-ton barrels of 16-in. guns taken from World War II battleships. In the technique, which is being used at General Electric's Lamp Metals and Components Dept. in Cleveland, tungsten powder is placed in watertight molds and is then compacted under a hydrostatic pressure of 25,000 psi. After being pressed, the tungsten slugs are then sintered to obtain strength and increased density. The sintered units can be machined, rolled or forged.

Size of ingots which can be made in the press is limited only by the dimensions of the rifle bore of the gun. Maximum dimensions are 12 in. in diameter and 60 in. in length. Largest of the preforms to be made was one weighing 160 lb. having a depth of 4¼ in. and diameter of 10 to 12 in. It will be machined as a throat insert for a rocket engine.

GUN BARREL SERVES AS HYDROPRESS
Metal Powders Are Compacted for Rocket Nozzles and Electrodes Used in Arc Melting

Pressing equipment is also being used to make electrodes of tungsten, molybdenum, and their alloys for consumable electrode vacuum arc melting.

From Here and There

Steel ingots 50 in. in diameter and weighing about 60,000 lb. are being made in a new vacuum melting furnace which recently began operating at the Watervliet (N.Y.) Works of Allegheny Ludlum Steel Corp. The furnace, probably the world's largest of this type, was built by Lectromelt Div. of McGraw-Edison Co. Like smaller versions, it will be used primarily for producing clean ingots of superalloys for forgings and plates for the aerospace industry.

Direct-Reduction Copper Plant Planned for Philippines

A plant which will produce copper strip, tubing and wire by direct reduction of low-grade ores (and copper-zinc concentrates) will be built in the Philippine Islands. These products will be made by a process which includes chemical leaching and gaseous reduction. The resulting copper powder will be compacted and rolled on equipment developed by E. W. Bliss Co., (see *Metal Progress*, November 1958, p. 142).

The new plant, to be built by Foster Wheeler Corp., New York, is expected to have an annual output of 14,000 tons of copper products, 100,000 tons of ammonium sulphate fertilizer and 5000 tons of zinc.

12th Western Metal Congress

Consolidated Program

Los Angeles, March 20 through 24, 1961

ASM American Society for Metals
(SNT) Society for Nondestructive Testing
(AIME) American Institute of Mining, Metallurgical and Petroleum Engineers
(ASTM) American Society for Testing Materials
(SAMPE) Society of Aerospace Material and Process Engineers
(AF) Air Force Aerospace Briefing Sessions

The detailed program for ASM and all cooperating societies is presented in the February issue of *Metals Review*.

All meetings at Ambassador Hotel, Los Angeles

Monday, March 20

9:00 a.m. – ASM Metals Research
9:00 a.m. – **SNT** Nondestructive Testing of Rockets and Missiles
2:00 p.m. – ASM Metals Research
1:30 p.m. – **SNT** Nondestructive Testing of Rockets and Missiles
2:00 p.m. – **AF** Advanced Systems Briefing
(Attendance at this session is restricted to individuals with proper Air Force security clearance.)

Tuesday, March 21

9:00 a.m. – ASM Process Metallurgy
9:00 a.m. – **SNT** Nondestructive Testing of Electronic Components
9:00 a.m. – **SNT** Panel on Isotopes in Industry
9:00 a.m. – **AF** Aerospace Materials Session
2:00 p.m. – ASM Panel on Value Engineering
1:30 p.m. – **SNT** Lester Honor Lecture
High Energy Nuclear Radiations, Their Implications for Industry
2:00 p.m. – **AIME** Materials at Their Highest Strength – Whiskers

Wednesday, March 22

9:00 a.m. – ASM Laboratory Methods
9:00 a.m. – **SNT** Nondestructive Testing in the Aircraft Industry
9:00 a.m. – **SNT** Nondestructive Testing in the Oil Industry
9:00 a.m. – **AIME** Vacuum Thin-Film Metallurgy
9:00 a.m. – **ASTM** Effects of Conditioning or Processing on Fatigue Characteristics of Metals
2:00 p.m. – ASM Panel on Heat Treating Steels and Heat Resistant Alloys
1:30 p.m. – **SNT** $elective Testing Means $avings
1:30 p.m. – **SNT** Nuclear Developments in Testing
2:00 p.m. – **AIME** Properties of Refractory Alloys

Thursday, March 23

9:00 a.m. – ASM Metallugry for Advanced Design
9:00 a.m. – **SNT** Nondestructive Testing in the Shipbuilding Industry
9:00 a.m. – **AIME** Plasma Arc Applications to Metallugry
9:00 a.m. – **SAMPE** Systems and Design Problems on Space Vehicles
2:00 p.m. – ASM Panel on Vacuum and Consumable Electrode Melting
1:30 p.m. – **SNT** $elective Testing Means $avings
1:30 p.m. – **SAMPE** Research and Development on Space Vehicle Materials

Friday, March 24

9:00 a.m. – **SNT** Educational Clinic on Nondestructive Testing
1:30 p.m. – **SNT** Educational Clinic

Producing for the New Technologies

MP

Special Report on Expanding Opportunities in the Fields of the Future . . . Aeronautics . . . Astronautics . . . Missiles . . . Satellites . . . Rocket Propulsion . . . Re-Entry Spacecraft . . . Electronics . . . Atomics . . .

This issue of *Metal Progress* is devoted to the technical capabilities required for manufacturing in the aerospace, nuclear and electronic industries. Their needs cover the entire industrial spectrum – metals, fuels, ceramics, plastics, cryogenics, coatings and instruments. Developments made to solve problems of the new technologies will benefit almost every branch of the economy, either directly or indirectly. The decade ahead will see the use of high and low-temperature alloys, special processing techniques, cermet and ceramic parts, new coatings and sandwich designs in many other industries.

Western Metal Show Issue

The B-70 . . . a Challenge for New Technology

The B-70 Valkyrie is the most advanced manned aircraft ever attempted on a production basis. To the design engineer, it means new demands as each drawing takes shape. To the manufacturing engineer, it brings tooling and fabrication problems which require technological innovations for each step. To the materials engineer, it represents the ultimate challenge for materials performance and for precision in processing.

The B-70 is not merely a Mach-3 stepping stone to faster aircraft. Because of the many factors that make Mach 3 (about 2000 mph.) the speed for maximum range, it is expected that the B-70 will be the forerunner of a new species of aircraft ranging from the bomber to missile launchers and commercial transports.

Metals and Fabrication Methods for the B-70

*By WAYNE A. REINSCH**

As the most advanced bomber yet envisioned, the B-70 will fly farther, faster and higher than any other airplane now known to be on the drawing boards. Production of the first plane will climax more than 14,500,000 engineering man-hours.

In designing the B-70, the desired factor, range, dictated the other two variables, speed and altitude – to reach the range desired, a delicate balance of speed and altitude was needed. Thus, to cover intercontinental distances, the aircraft has to fly at 70,000 ft. at a rate of over 2000 miles per hr. (Mach 3). These basic design parameters establish the structural requirements in that they make it necessary to allow for a huge volume of

*Supervisor, Material and Process Engineering, Los Angeles Div., North American Aviation, Inc.

fuel to supply six mammoth jet engines. This leads to a welded construction, using the skins of the aft fuselage and wing as integral fuel tank shells. The speed and altitude result in skin temperatures of 450 to 630° F. This means that steel and titanium alloys must be selected for the major structural materials. Engine compartment temperatures up to 1600° F. require that nickel and cobalt-base superalloys be specified for internal structures. Finally, these materials must be assembled to provide fuel tightness, thermal insulation, resistance to acoustic fatigue and corrosion – employing maximum structural efficiency for minimum weight.

Honeycomb for Strength and Heat Resistance

Steel honeycomb fabricated into a sandwich by brazing was selected for major areas of the B-70 where maximum structural loads combined with skin temperatures of 450 to 630° F. are encountered. This type of construction provides optimum structural efficiency and excellent thermal insulation (to limit the temperature rise of the fuel), and it can be welded.

The sandwich consists of facing sheets and honeycomb core of corrosion resistant PH 15-7 Mo steel with various edge members and fittings – all joined with a silver-base brazing alloy as illustrated in Fig. 1. The brazing is done concurrently with the first stage of heat treatment at 1725° F. This is followed by subzero cooling, and aging. The ceramic forms in Fig. 2 illustrate the variety of honeycomb shapes needed for the B-70, while Fig. 3 shows steps in the electric blanket brazing process.

The speed and altitude of the B-70 results in skin temperatures of 450 to 630° F., which means that steel and titanium alloys must be used as structural materials. An all-brazed hydraulic system for operation at 450° F. and 4000 psi. gives considerable weight savings. Revealed here for the first time are details on types of metals and the precision techniques employed in fabrication of the B-70 – the new technology which someday may provide a fleet of airliners that will fly three times the speed of sound. (T24, G-general, K8, 17-57; SS, Ti-b, TS, SGA-h)

The PH 15-7 Mo* facing sheet is produced by Armco Steel Corp. to a degree of metallurgical and dimensional control never previously achieved in a sheet product of this kind. The balancing of the austenite-stabilizing elements – carbon, nickel and manganese – with the ferrite-forming elements – chromium and aluminum – produces the distribution of ferrite and tempered martensite desired in the heat treated and aged product. This balance also results in a reproducible M_s temperature of about 150° F., which is important during brazing because each panel contains many parts that often represent several different alloy heats. A reliable M_s thus assures that all parts of a panel begin to transform and grow simultaneously during cooling. Thus, stresses and warpage are minimized, and dimensional control is maintained.

The narrow limits held for aluminum content also give a predictable response to age hardening. The precision to which alloy PH 15-7 Mo is produced confines the variation in tensile strength to 15% when parts are heat treated to the 200,000 to 230,000-psi. level. This is considered outstanding for an alloy of this metallurgical complexity.

Processing PH Steel Sheet

The PH 15-7 Mo sheet for the B-70 is rolled on a Sendzimir mill, then is stretcher leveled. Thickness tolerance is ±0.001 in. in sheet up to 44 in. wide and in gages up to 0.100 in. Requirements on flatness and finish are critical.

The facing sheets go through a number of processes before they are ready for brazing. The relatively high density of steel for aircraft structures requires that excess metal be removed, even in localized areas. This is done by chemical milling, machining and grinding. Some areas are pocketed to several depths, others are tapered. Facing sheets are usually made up of a number of individual parts, prepared as described above, then fusion welded to form an assembly for brazing.

*Additional information on the general characteristics of PH 15-7 Mo is given in *Metal Progress* for March 1959, p. 121.

Fig. 1 – Assembly of Panel for the B-70 Prior to Brazing Includes Silver Brazing Alloy (Right), Honeycomb Core of PH 15-7 Mo Steel, Facing Sheets and Edge Members

Parts are also machined from plate, bar and extrusions of both PH 15-7 Mo and AM 355 alloys. In these applications, AM 355 is used where stock thicknesses exceed ½ in. to take advantage of its excellent transverse ductility.

Processing Honeycomb Core

Honeycomb core for the B-70 is fabricated from PH 15-7 Mo foil, 0.00075 to 0.004 in. thick. The tolerance limits for the foil are 5% of the nominal thickness. Thus, the tolerance for 0.001 in. foil is ±0.00005 in.

This remarkable product which was developed for the B-70 by the Wallingford Steel Co. is made on a Sendzimir mill in widths up to 23 15/16 in. The foil is produced in two conditions, annealed or partially cold rolled. Annealed material is used for core blankets which require forming to contour. Partially cold rolled material, designated "½ C", is used for flat core, and it has better machinability than the annealed material. The foil is given an inhibited pickle after the final anneal to remove any oxides which would impair brazing.

Foil is made into honeycomb core with square-shaped cells of sizes ranging from ⅛ to ¼ in. To extend the depth of the core, cells are joined at their corners by intermittent resistance welds. The welded zone, called a node, is the most important part of the core from a structural standpoint.

The core is made by one of two methods. In one, the foil strips are preformed, then welded. In the other, called the HOBE method, welding is done in the flat, then the core is expanded to obtain the correct cell configuration.

The Brazing Alloy

The brazing alloy used to join the facings and core for the sandwich must meet a number of difficult requirements. To serve its purpose properly, this alloy must:

- Provide adequate brazed fillets for the core to face bond.
- Flow uniformly along the core nodes to boost column strength.
- Possess low thermal conductance so that the insulating property of the sandwich panels is not impaired.
- Remain in place on curved panels, rather than flow to the low points.
- Produce a braze at a temperature compatible with the heat treating cycle of PH 15-7 Mo steel.

Development of a brazing alloy to satisfy

Fig. 2 – Size and Contour of Various Honeycomb Sandwich Parts To Be Made for B-70 Are Illustrated by These Ceramic Faces for Electric Blanket Brazing

Fig. 3 – View of Three Electric Blanket Tools for Brazing in Various Stages of Preparation. Shown (front to rear) are: Resistance heaters over ceramic form; resistance heaters covered by insulator and glide sheet, and complete assembly with top half of tool in place

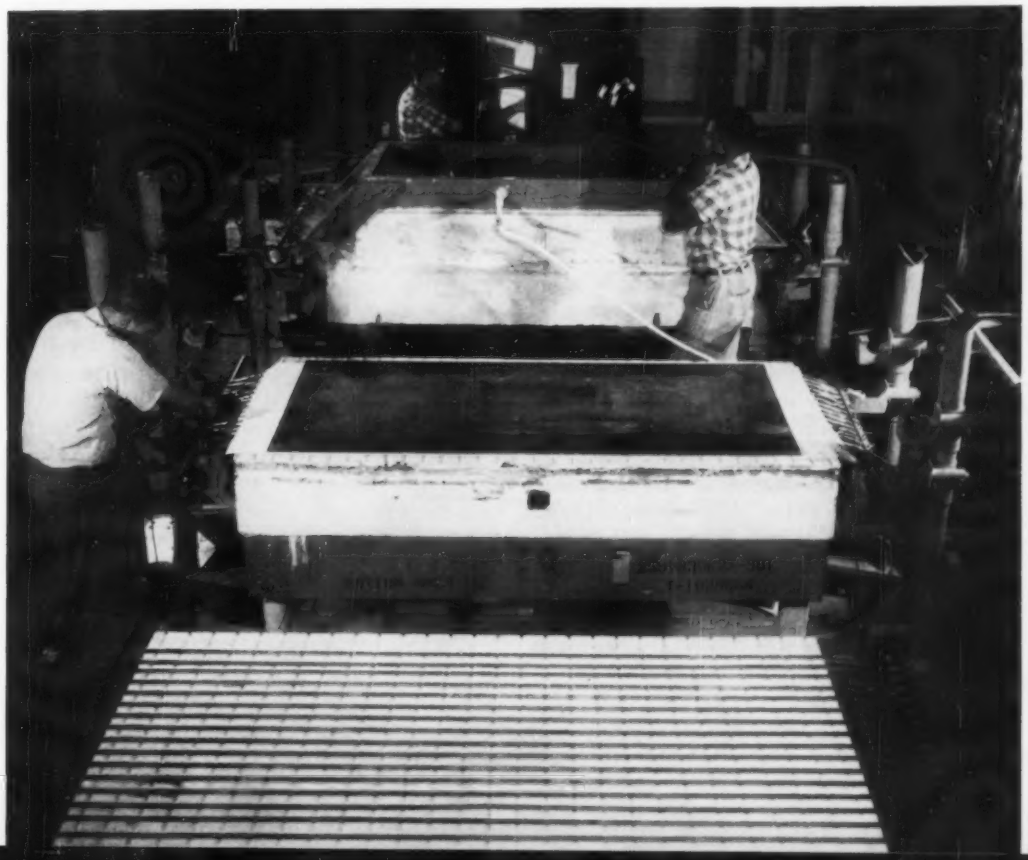


Fig. 4 – Structural Test Section of B-70 Wing Consists of Upper and Lower Panels of Brazed PH 15-7 Mo Panels and Sheet Metal Bulkheads

these needs was a formidable problem which was solved through the joint efforts of metallurgists at North American's Los Angeles Div. and the research staff of Handy and Harman. The alloy is a silver base (84.6%) alloy which brazes at 1725° F. Indium (5.5%) is added to reduce the high thermal conductivity that is characteristic of silver. Palladium (2.2%) is added to raise the brazing temperature so it will be compatible with the first stage of heat treatment of the PH 15-7 Mo steel. The alloy also contains 0.2% lithium for self-fluxing (a principle which has been successful in other brazing alloys) and 7.5% copper. To control alloy drainage in curved panels, a nickel dispersion (20 vol.%) is added to the braze.

Titanium Structures in B-70

Structural components of titanium alloys are used extensively in the forward fuselage sections and in the horizontal stabilizer. Since these are not fuel-containing areas, a skin and frame-type structure assembled by mechanical fasteners is used. These areas must withstand flight temperatures of about 550° F. and, under the loads imposed, the skin and frame titanium structure provides a weight advantage over steel honeycomb.

Two heat treatable sheet alloys are employed. For parts requiring welding, 6 Al, 4 V sheet is used. For parts requiring maximum formability 4 Al, 3 Mo, 1 V sheet is preferred. Sheets are chemically milled to achieve the required thickness tolerances of +0.000 to −0.002 in. The alloys are purchased in the annealed, solution-treated, or the solution-treated and aged condition, depending upon fabrication sequence for the individual parts. Both alloys are used at a tensile strength of 160,000 to 190,000 psi.

The substructure is fabricated from parts machined from bar, forgings and extrusions of titanium alloy 6 Al, 4 V and 7 Al, 4 V which are subsequently heat treated and aged. Ribs for the horizontal stabilizer are of a modified I-beam type (Fig. 5). They consist of caps and webs joined by "burn-through" fusion welding (tungsten inert gas). The webs are of a sine wave configuration. Welding the sine wave geometry from the cap side and concurrently adding filler metal at the proper rate has required ingenious techniques.

For assembly of larger skin areas of mild curvature, 6 Al, 4 V sheet is purchased in the solution-treated and aged condition, chemically milled to the required thickness tolerances, then welded, followed by a stress-relief at 1000° F. for 30 min.

Fabricating of H-11 Steel

A.I.S.I. Type H-11 steel is used in many internal structural areas of the B-70 fuselage, wing and horizontal stabilizer, as well as in the landing gear struts and related mechanisms. The alloy is a 5% Cr, 0.40 C air hardening material. Fabricated parts are heat treated to a tensile strength of 280,000 to 300,000 psi. The high strength and high modulus of the material justify the great care required in processing these assemblies. Also, the notch sensitivity of such a high-strength material demands that all possible precautions be taken to minimize stress concentrations.

For the B-70, these precautions begin with the requirement that all material be vacuum melted by the consumable electrode process. Surface conditions are carefully controlled. Areas which are critical in fatigue are required to be free from decarburization. Less critical

areas permit no complete decarburization and a maximum depth of partial decarburization of 0.003 in. These limitations have been established with full knowledge of the opinion sometimes heard that "controlled decarburization is beneficial". A fine surface finish (8 and 32 rms.) and shot-peening further assure maximum resistance to fatigue.

Precautions in Fabricating H-11 Parts

The H-11 structure includes many types of parts, among which are large welded frames with thin webs and caps. Many parts require threading, straightening or grinding. Each process is a potential source of trouble; a few of the necessary limitations are given below:

1. **Threads** – When made to the MIL-S-7742 configuration, they must be rolled. Acme, Whitworth, or "radius root" threads may be rolled or ground.

2. **Welding** – Preheat and postheat treatments are required. Welds are made while the part is maintained at 600° F. Weldments must be fully annealed before heat treating.

3. **Cold straightening** – When applied to heat treated parts, cold straightening must be followed by stress-relieving at 925° F. for 2 hr.

Fig. 5 – Modified I-Beam Rib for Horizontal Stabilizer of B-70. Rib consists of a web with a sine wave configuration welded to the caps

4. **Rough edges** – Burrs, deep scratches and rough edges must be removed before the part is heat treated.

5. **Grinding** – Care is required to prevent checking, and all grinding must be followed by stress-relieving at 925° F. for 2 hr.

Corrosion protection is provided in several ways, depending upon function of the part and service temperature. Sprayed aluminum coated with a silicone resin is used for some parts with service temperatures up to 900° F. A nickel-zinc electroplate coated with a silicone resin protects other parts for the same service temperatures. Vacuum-deposited cadmium is used for some applications where service temperatures do not exceed 500° F.

Brazed Hydraulic Lines and Components

The hydraulic system of the B-70 is designed to operate at a pressure of 4000 psi. at 450° F. It is made up principally of AM 350 steel tubing for lines, and AM 355 and H-11 for fittings and components.

The AM 350 steel used in tubing for the lines is an alloy developed by Allegheny Ludlum Steel Corp. It is produced as a special temper in tube form for the B-70 by Wallingford Steel Co. and Trent Tube Co. The tubing is made by fusion welding of strip, then cold drawing with intermediate anneals, and finally giving the product a cold draw to reduce wall thickness about 30%. Final drawing is followed by an aging treatment at 850° F.

The AM 350 alloy is an austenitic precipitation hardening stainless steel, metastable at room temperature in the annealed condition. During the final reduction in the tube-drawing process, strain transformation occurs resulting in a structure of cold worked martensite, cold worked austenite, and cold worked ferrite. The aging treatment stabilizes the remaining austenite to assure that no further transformation will occur during service. This treatment also tempers the existing martensite, and age hardens the alloy.

This metallurgical structure provides a rather remarkable combination of properties, which give adequate strength for design and good forming characteristics. Minimum values of 175,000 psi. ultimate strength, and 140,000 psi. yield strength are consistently produced. An elongation of 30% in 2 in. is typical; it permits a bend radius as small as three times the tubing diameter to be used.

The complex arrangement of the hydraulic

system will require about 5000 joints in the installed tubing. They must be of minimum weight, and capable of being installed in very congested areas. Induction brazing with lightweight sleeves has been developed to meet these requirements. The sleeves are machined from AM 355 precipitation hardening steel and are grooved internally to accept the preformed rings of brazing alloy.

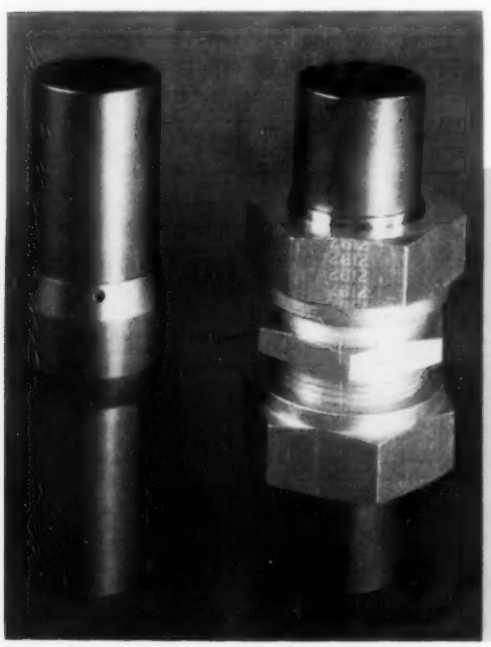
The brazing alloy is a silver-base alloy, containing lithium for self fluxing, which brazes at about 1500° F. Joints are made by assembling the tubes and the sleeve containing the brazing alloy, positioning the induction heating coil with a purging chamber, purging with argon, and finally heating. The process illustrated in Fig. 6 has been developed to a degree which is efficient and reliable.

Brazing Saves Weight in Components

Assembly by brazing saves weight in fabricating hydraulic cylinders and valves. These are made of H-11 steel, brazed to other H-11 parts or to Type 321 stainless steel details, and AM 355 steel, brazed to AM 350 steel tubing. In these designs the high strength and high modulus of elasticity of H-11 steel are important. A tensile strength of 260,000 to 280,000 psi. provides high bursting strength and high bearing strengths at attachments. The high modulus of 31,000,000 psi. minimizes the deflection of cylinder walls under high pressure and permits the required seal to be maintained between pistons and cylinder walls.

These assemblies are brazed and heat treated concurrently in a manner similar to that described earlier for brazed sandwich. The H-11 is first transformed and tempered to produce the required dimensional stability and machinability. This is followed by finish machining, and stress-relieving at 800° F. Parts are then assembled in the retort with preplaced rings of brazing alloy (82% Au and 18% Ni). The assembly is next austenitized and brazed concurrently in a hydrogen atmosphere at 1850° F. Finally, the assembly is triple tempered at about 1000° F. Figure 7 shows a typical H-11 steel cylinder brazed to Type 321 stainless lines with the process control tensile bar included.

Valves and fittings employ AM 355 steel bodies brazed to segments of AM 350 tubing where subsequent joining to AM 350 hydraulic lines is required (Fig. 8). The process is similar to that described for H-11 except that the 355 is brazed to 350 with a silver-base alloy, which has a brazing temperature (1710° F.) compatible with the austenite-conditioning temperature of the precipitation hardening steels. Brazing is followed by subzero cooling and tempering at 850° F.



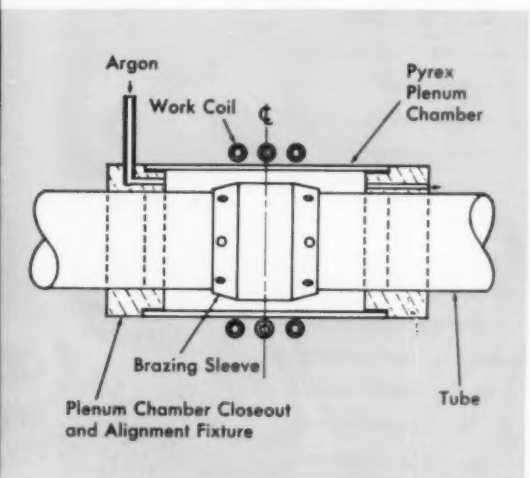


Fig. 6 — Brazed Joint for B-70 Hydraulic System (Left) Compared with Conventional Joint Employed in Aircraft. About 5000 joints are required in the complex hydraulic system of the B-70. Drawing (right) illustrates tooling used for brazing tubing

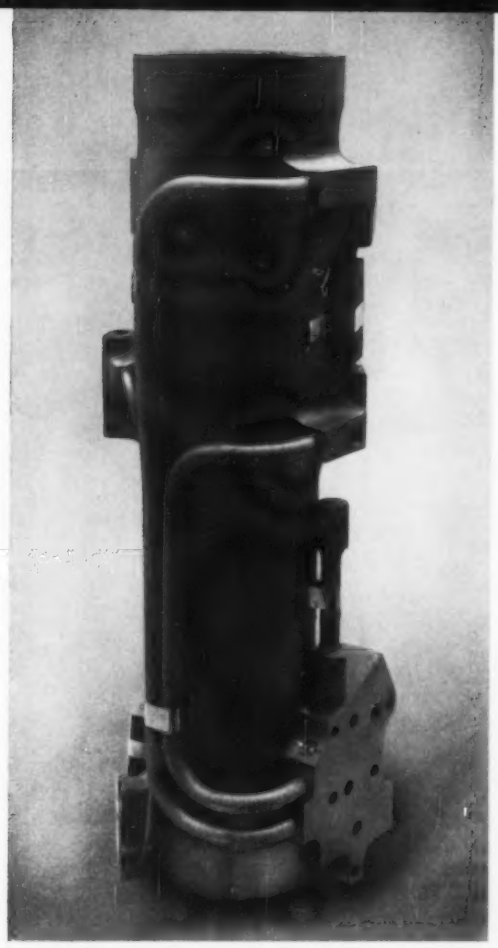


Fig. 7 – Typical Hydraulic Actuator Cylinder Showing H-11 Steel Barrel Brazed to Type 321 Stainless Steel Lines. Process control coupons are included for tensile and decarburization tests

Service temperatures of the B-70, except in the air-conditioned crew and electronics compartments, also pose severe problems for the nonmetallic materials engineer. It is planned to produce landing gear tires from butyl rubber with HT-1 nylon fabric reinforcement. Wheel wells will be insulated to limit the temperatures to the maximum capability of this combination, about 360° F. The hydraulic system, operating at about 450° F., demands that conventional fluids be abandoned in favor of Oronite 8200, a disiloxane ester. Radomes require glass cloth impregnated with silicone resin, and dielectric isolators designed to carry structural loads employ glass cloth impregnated with phenyl-silane resin.

The Challenge of the Future

The task of developing materials to meet advanced capabilities of the B-70 has rested mainly with the suppliers of materials. Responsibility for design, process development, and acquisition of fabrication skill has been carried by North American and by the subcontractors participating in the program. The vast progress in materials technology represented by the B-70 is due to the foresight of the program sponsor, the U. S. Air Force.

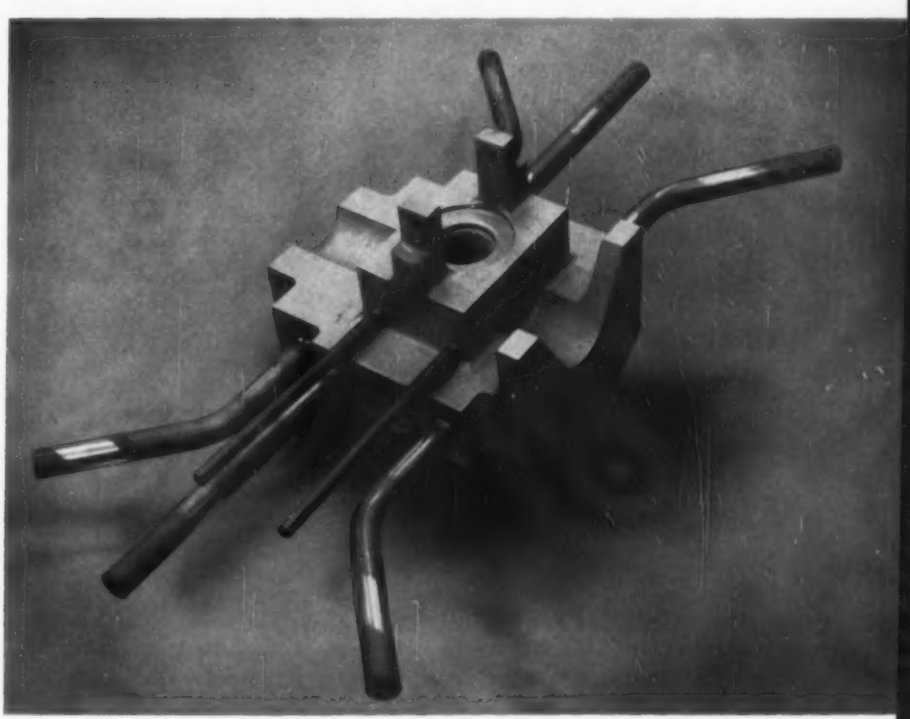
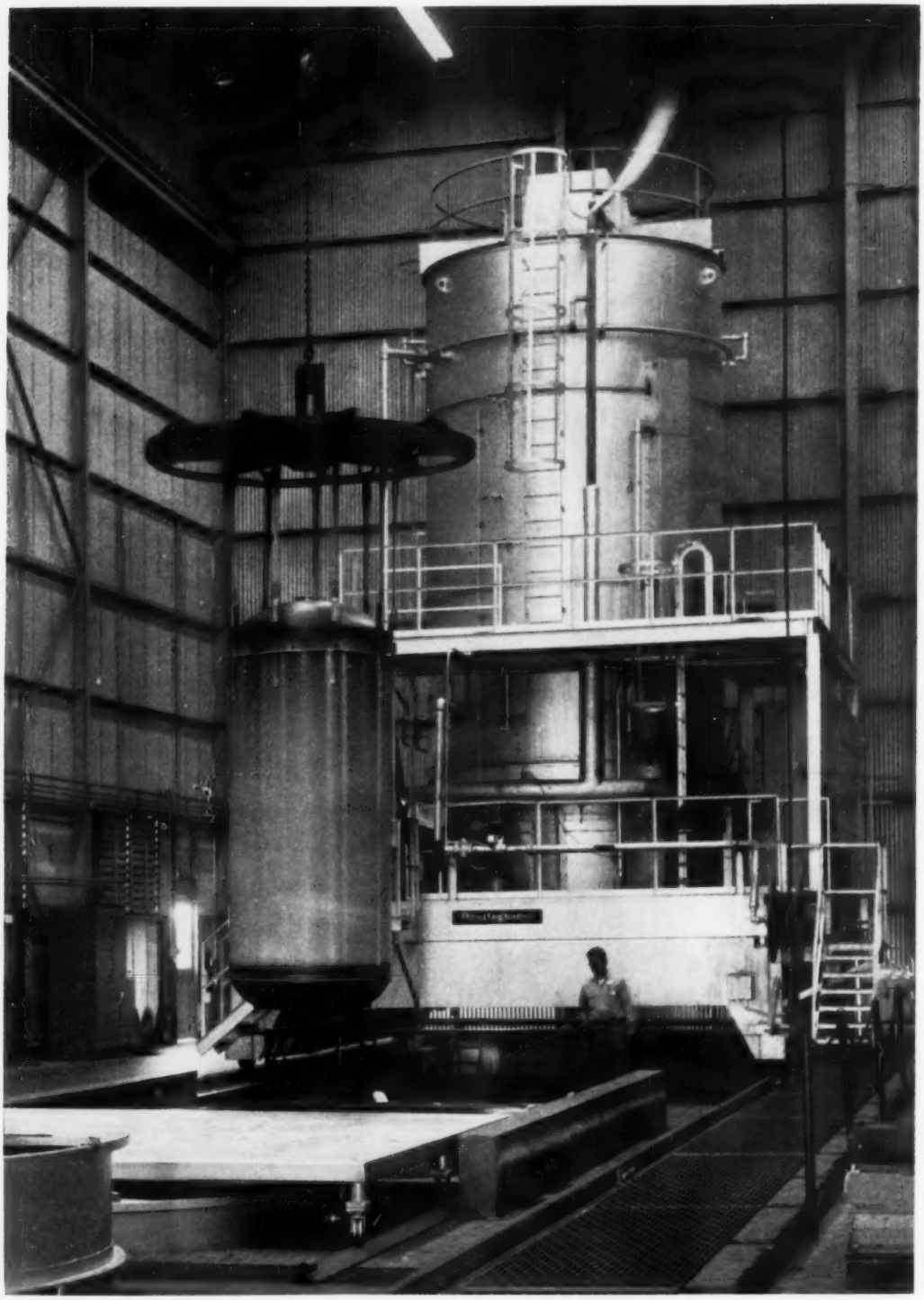


Fig. 8 – Hydraulic Valve Fabricated by Brazing AM 355 Steel Body to Tubing Segments of AM 350 Steel



Large Gantry Furnace Ready to Heat Treat a Rocket Motor Chamber. Capable of heat treating chambers up to 100 in. in diameter, this unit is one of the largest in the world today

For Stronger Missile Cases ...Decarburize!

*By JOHN M. LYNCH**

The trend to higher strength in sheet steels for rocket cases has been slowed by two drawbacks: the drop in toughness and the increased susceptibility toward notch sensitivity which goes along with these greater strengths. Surface decarburization is suggested as a means for toughening the sheet surfaces. This article describes some of the methods, advantages and difficulties of the process. (J4a; ST, AY)

IN THE FABRICATION of rocket and missile cases there has been a trend toward thinner-gage wall thicknesses. The reason? To increase the range by reducing the inert weight. Of course, as the wall thickness is decreased, the alloy's strength must be increased so that internal pressures (from hydrostatic testing and the internal pressure of gases generated during burning of the propellant) will not rupture the vessel.

However, there is a problem connected with obtaining ultra-high strength levels in steel. As the strength is increased, there is a corresponding decrease in toughness of the metal. This difficulty is somewhat magnified by the detrimental effect of notches which can readily result from mishandling during fabrication.

To explain further, the rocket or missile case is a composite of a shell, fore and aft heads, and skirts. After being fabricated, all components are welded together and the assembly is heat treated. Continual handling and fixturing subject it to nicks, scratches, gouges and areas of mismatch which may cause catastrophic failure under pressure.

One method for reducing the detrimental effect of these processing flaws is to decarburize the surface. This creates a sort of "skin", more ductile and less notch sensitive than the harder core material. Using the norm that a G_c† value of 1000 reflects good toughness, it can be observed in Fig. 1 that 4 to 6 mils of decarburization significantly increases the toughness above a 500° F. tempering level. It can therefore be assumed that this particular material (Ladish D 6 AC) has good fracture toughness at and below the surface within the limits of the effect of the decarburization.

Controlling Decarburization

By definition, decarburization is the loss of carbon from the surface of steel which occurs when the alloy is heated in an atmosphere that reacts with the carbon. When setting up a decarburization cycle for use in the final heat treatment, several things should be kept in mind.

The hardening atmosphere normally used in the heat treatment of rocket and missile cases is an endothermic gas. Since neither carburizing nor decarburizing is normally wanted, the gas is usually maintained in equilibrium with the carbon content of the steel at the hardening temperature. In most instances, the atmosphere is controlled through dew point analysis. Figure 2 shows a typical dew point chart.

For hardening missile cases, preheating is generally required before austenitizing. How-

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†"G_c" units are used in giving quantitative values for fracture toughness. For further information, see the "Special Feature on Brittle Fracture of High-Strength Steels", *Metal Progress*, August 1960.

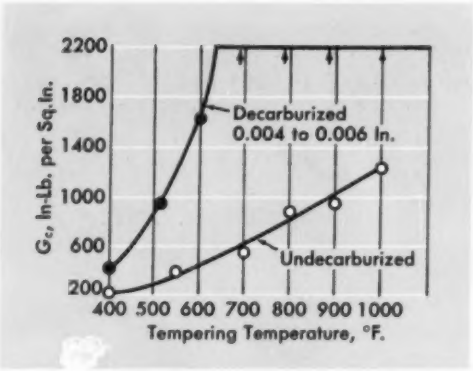
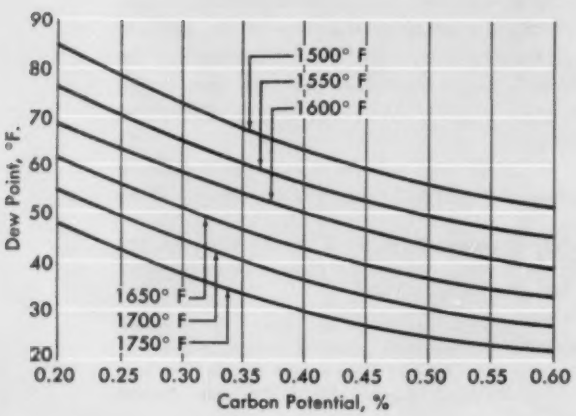


Fig. 1 — Fracture Toughness Comparison of Normal and Decarburized Ladish D 6 AC, 0.072 in. thick. Deliberate decarburization significantly raises the toughness, particularly at high temperatures

ever, this extra operation entails problems. In preheating at subcritical temperatures, oxides often form on the surface because protective atmospheres are not generally used. These oxides must be removed if the surface is to be uniformly decarburized. Also, preheating at or near the critical temperature will normally produce a decarburizing reaction which will subsequently change to a carburizing action. As a result, though sufficient time must be allowed at this temperature to lessen thermal shock, prevent distortion, and initiate surface oxide reduction, it should not be long enough to restore carbon.

Fig. 2 — Equilibrium Dew Points for Various Carbon Potentials and Temperatures. Adjusting the atmosphere dew point for an equilibrium at a temperature between the preheat temperatures and the austenitizing temperature will result in decarburization when the austenitizing temperature is reached



To produce the desired reducing-decarburizing cycle, one can select a process dew point which is in equilibrium halfway between the preheating temperature and the austenitizing temperature. As an example, for a steel with 0.45% carbon, the normal preheating temperature would be 1400° F. (the safe temperature above ignition) and the austenitizing temperature 1600° F. Obviously, the temperature midway between 1400 and 1600° F. is 1500° F. — and this, according to Fig. 2, requires a +60° F. dew point for equilibrium. Gas with this dew point decarburizes at the austenitizing temperature (1600° F.) with a potential of only 0.28% carbon. Depth of penetration then depends on the length of time at 1600° F.

Endothermic and Exothermic Atmospheres

Partial decarburization obtained from a properly controlled endothermic atmosphere (with particular attention to the hardening cycle requirements) will result in a carbon gradient from surface to core material which is comparatively gradual. Depending of course on steel gage and depth of penetrations, there is little or no change in yield strength.

Two factors affect this process: chemical reaction between surface and surrounding atmosphere, and the diffusion of free and interstitial carbon from areas of high concentration to areas of low concentration. Unrefined exothermic atmospheres almost completely decarburize the surface because of their high dew points and high CO_2 contents. However, although they produce a tough, low-carbon layer, the over-all loss in strength may be prohibitive, and quite often free ferrite is obtained, resulting in poor fatigue properties. As for other drawbacks, sufficient control for proper decarburization is difficult when using unrefined exothermic atmospheres, and refined exothermic atmospheres require auxiliary equipment. This adds to the expense.

Testing for Decarburization Depth

To determine the depth of the decarburized layer, a microhardness traverse check of a specimen mounted in bakelite is quite acceptable. Of course, one of the problems in making this type of traverse is the edge effect. As a check of the mounted specimen, therefore, a tapered bar (Fig. 3) is being investigated so that more accurate surface and near-surface

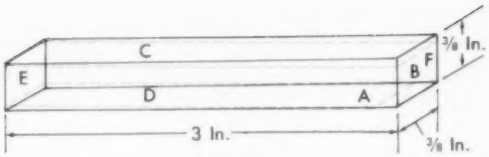


Fig. 3 – Tapered Microhardness Specimen. This test piece is decarburized along with the missile case; after heat treatment, specimen is tapered by grinding sides C and D as indicated. Taper on both sides is 0.008 in. per in. but on side D it begins a short distance from the end (F). Microhardness measurements start at A and B

results can be obtained. Hardnesses can be determined very close to the surface at many points across the specimen width. As an added precaution, the taper, on the side to be checked for hardness, should not start at the end of the bar, but at a short distance from the end.

Conclusions and Recommendations

Surface decarburization and depth of penetration can be controlled within very narrow ranges, and such partial decarburization increases toughness values. To produce decarburization, an endothermic atmosphere is better than an exothermic atmosphere because it is more reliably controlled and there is less chance for significant strength losses. Depth of penetration depends on the length of time at the austenitizing temperature.

However, more investigation of differential decarburization is required. Certain joints, rings, and bosses are machined after heat treatment, and, as a result, the decarburization that was present in these areas is removed. To gain the full benefit of the process, such areas should be decarburized much more deeply than areas which are not subsequently machined. Variations and combinations of the following three methods should be investigated for differential or selective decarburization:

1. Multiple hardening cycles employing protective coatings on surfaces where no further decarburization is necessary.
2. Annealing cycles to produce decarburization of forgings for bosses and rings prior to the welding of the subassemblies.
3. Application of a chemical such as a thick slurry of commercial yellow ochre in methyl alcohol to produce local decarburization.

Also, further investigation should be conducted to determine the relationship of partial decarburization to a tolerable fatigue cycle.

Materials for Uncooled Rocket Nozzles

*By A. V. LEVY**

Though molybdenum and tungsten are being used today for uncooled rocket nozzles, rising temperatures are expected to bring in more durable graphites, carbides and ceramics.
(T2p, 17-57; SGA-h, Mo, W, NM-f, NM-k36, 6-69)

WHEN PERFORMING THEIR FUNCTIONS, the throats of uncooled rocket nozzles range from 5000° F. to above 6000° F. – the highest temperatures to which materials are exposed today. Even more severe environments are coming. Future service requirements for such nozzles will follow a varying pattern of combinations. Among other things, designers must consider temperatures to 7000° F. and above, long sustained or cyclic firing periods of several minutes duration, very low to extremely high combus-

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tion chamber pressures, and varying chemical reactivity. A combination of these severe operating conditions can occur, thus making the material problem still more complicated. To illustrate this, here is a brief discussion of the types of materials that have withstood the operational environment of a rocket nozzle and some predictions for the future.

Refractory Metals Are Successful

Nozzle throats machined from molybdenum forgings (both arc-cast and powder-metallurgy product) have been successful up to 4900° F. More recently, machined billets of pressed and sintered tungsten and arc-cast 85% tungsten, 15% molybdenum alloy have been used as massive inserts in rocket nozzles exposed to propellant temperatures of 5400° F. However, there has been a need to reduce the weight of the insert. This has been answered by methods for hot spinning thin liners of tungsten sheet; these liners can then be bonded to graphite back-up structures. As alternate methods, plasma flame spraying and vapor deposition from the halides have also been used to "build" a tungsten skin on a graphite insert.

In the form of spun sheet (or plasma or vapor-deposited coating) on graphite, tungsten appears to be facing a relatively long career in the rocket-motor field. Other uses for refractory metals, especially molybdenum, are on the decline. As for the future, even tungsten will be limited by operating temperatures above its melting point, 6150° F., and the presence of free oxygen in the combustion gases (as in some liquid-fueled rocket motors).

Refractory metals in sheet form can also be used for coolant reservoir-type rocket nozzles as an alternative to uncooled nozzles. In this application, an annular chamber is built around the nozzle throat area so that a refrigerating fluid can be pumped through the reservoir to cool the nozzle flame surface. Complex fusion weldments of refractory metal sheet will be used in fabricating the chamber.

Potential for Graphites and Carbides

At least two advances in graphites hold considerable promise for the rocket-nozzle field. Both pyrolytic graphite and the new high-density, pressure molded graphite (the ZT series, for example) have performed well in rocket test firings. Their low erosion rates help to hold changes on nozzle areas within limits. Today, both materials are being developed to improve consistency, erosion resistance and size capability. With such improvements, reliable nozzles with throat diameters in excess of 2 ft. can be expected in both solid and liquid rockets.

Carbides with high melting points are also being considered for uncooled rocket nozzles. As operating temperatures approach and exceed 6000° F., the carbides of hafnium, tantalum, zirconium, columbium and titanium, and combinations of carbides with melting temperatures above 7000° F. represent the furthest possible extension of materials for components of uncooled rocket nozzles.

However, the eventual use of these materials will depend upon the results of development work presently underway. So far, the extreme sensitivity of the carbides to thermal shock has prevented them from being used in massive pressed and sintered shapes. Recently, this problem has been partially solved by combining the carbides with refractory metals in fiber form. It is expected that carbides reinforced with tungsten fiber will soon produce a new group of materials for uncooled rocket nozzles.

As another approach to this high temperature problem, graphite surfaces can be converted to high-melting carbides by direct chemical reaction with metals deposited by vapor deposition, direct melting or flame spraying. Conversion temperatures for this process are well within the realm of practical processing techniques.

Ceramics Show Promise

Ceramic oxides have been considered for rocket-nozzle application, but thermal shock sensitivities, spalling tendencies, and low melting temperatures have restricted their use. In this area, present work is aimed at producing a metal fiber, wire or honeycomb-reinforced oxide body that can be impregnated with a subliming material. This material will ablate during service to cool the oxide surface. Here, the intention is to produce a statically cooled system that will not erode at extreme temperatures and will have good thermal shock resistance and chemical stability in an atmosphere containing excess oxygen.

The oxides presently being investigated include zirconia, thoria, magnesia and hafnia. Refractory metals, particularly molybdenum and tungsten, are being used to reinforce the ceramic, and the best impregnants, from both a thermodynamic and fabrication standpoint, are phenolic resin and molybdenum oxide. The future use of ceramic oxide nozzles will depend on whether their thermal shock resistances and low melting temperatures can be improved.

Fabricating the Titan Propulsion System

*By W. M. BOAM**

Materials problems in design and fabrication of liquid-fueled rocket engines stem from a wide variety of conditions which are encountered. In designing the engine for the Titan ICBM, engineers have come up with a complex but reliable package which mates metals and nonmetals. (T2p, K-general, K8, SS, AY, SGA-h, Ni-b, Al-b)

THE ENGINE FOR THE AIR FORCE TITAN ICBM is the result of the difficult transition from theoretical research to design and production. Fueled by kerosene (RP-1) and liquid oxygen, it poses numerous problems in the selection and fabrication of materials. The effect of the extreme temperatures ranging from those encountered in the combustion chamber to those in the oxidizer system must be carefully evaluated. In addition, the severe penalties in performance which weight imposes have made it mandatory to use lower safety margins than are found in conventional structural design. Thus, materials for the propulsion system – frame, turbopump assembly, thrust chamber, transfer passages and control system – can be selected only after a thorough evaluation of reliability.

Brazed Combustion Chamber

Currently, the combustion chamber for the Titan propulsion system (Fig. 1) is made up of numerous preformed tubes with 0.020-in. walls brazed together in the form of the familiar hourglass shape. Brazing of Type 347 stainless steel tubes, through which fuel is circulated to cool the chamber, is performed in an atmosphere of dry hydrogen using A.M.S. 4777 as the braze alloy. This method is readily adaptable to standard facilities and has several advantages over other widely used fabricating methods.

Recommended Brazing Technique

For best results during brazing, the joint clearances between tubes must not exceed 0.001 in. About 0.3 g. of braze alloy is applied per linear inch of joint and is held in place with Nicrobraze cement. The assembly should not be handled until the binder becomes effective.

Brazing is carried out in a sealed retort (Fig. 2) which is first purged with argon and dry hydrogen (dew point −80° F. or lower) using about six changes of atmosphere, based on the volume of the retort, before lighting the exhaust gas. Hydrogen in the retort should be displaced at least seven times per hour during brazing.

Once flushing is completed, the retort is covered with a bell furnace as shown in Fig. 3 which is preheated to 1000° F. Temperature is increased again to 1800 to 1900° F. where it is held for 5 min. It is then lowered to 1650° F. and the bell furnace is removed. The retort is covered with a water-cooled hood as shown in Fig. 4. Hydrogen flow in the retort should be continued until the retort cools to below 600° F. The retort is then purged with argon; when

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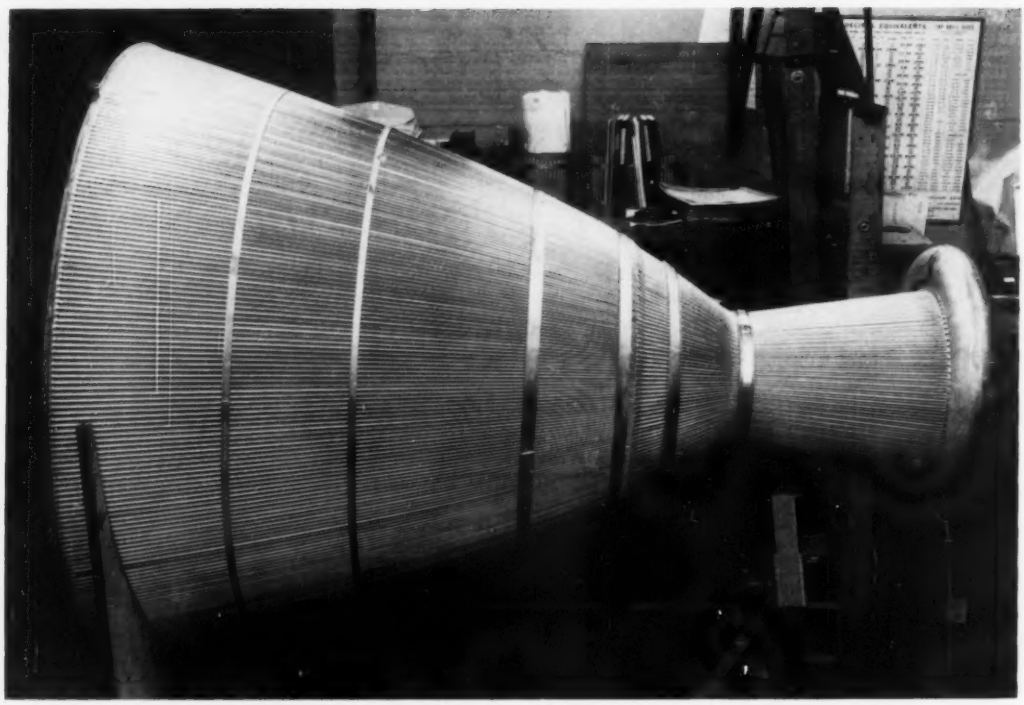
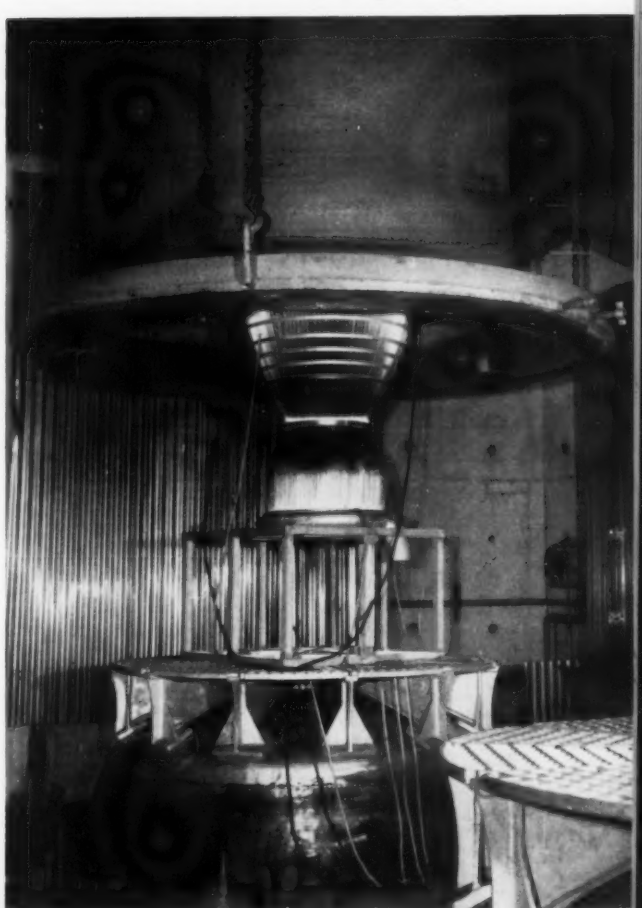


Fig. 1 – Combustion Chamber for Titan Engine Is Made From Preformed Type 347 Tubing Brazed in Dry Hydrogen

Fig. 2 – Retort Filled With Dry Hydrogen Protects Combustion Chamber During Brazing



cooled to 300° F., it is lifted from the combustion chamber.

Oxidizer and Fuel Systems

The oxidizer system, which operates at about −290° F., requires materials which possess the highest degree of ductility at extremely low temperatures. Best for this purpose are the nickel, copper, aluminum and the austenitic alloys. The nickel-bearing low-alloy steels in the quenched and tempered condition and the semi-austenitic stainless steels such as 17-7 PH and AM-350, heat treated to intermediate strength levels, are also suitable for low-temperature service.

The fuel system does not require the same low-temperature ductility and thus offers more flexibility in selection. For standardization and economy, however, the same materials should be used for both systems where feasible.

Investment-Cast Blades

The present concept for the turbine section of the turbopump assembly consists primarily of two assemblies brazed in dry hydrogen. One

of these is an inlet manifold cast in Type 347 stainless steel to which investment-cast N-155 nozzle blades are brazed. The second is the rotor assembly of investment-cast Haynes Stellite 21 turbine blades brazed to a forged disk of A-286. The braze alloys employed are A.M.S. 4777 and 4775. Connecting the turbine rotor and the pump impeller is a gear train machined from A.I.S.I. 4620 carburizing steel. The pump assembly consists primarily of a cast aluminum (A-356-T 6) pump housing, a forged impeller (7075-T 6), and an impeller shaft made from "K" Monel or AM-350 S.C.T.*

The frame which attaches the engine to the missile is a welded tubular structure of A.I.S.I. 4130 steel. Portions of the assembly are heat treated separately to a yield strength of 165,000 psi. (0.2% offset). These subassemblies are welded together after heat treatment.

Transfer passages and the control system consist of valves and the lines which carry the propellants from the tanks to the pumps and then the injector. The fuel and oxidizer passages are welded Type 347 stainless steel. Their internal supports at universal joints are welded AM-350 S.C.T. possessing a yield strength of 135,000 psi. (0.2% offset). The fuel valves consist of a carburized, 9310 steel shaft, cast aluminum housings (A-356-T 6) and aluminum gates (7075-T 6) coated electrochemically with a hard, corrosion resistant film. Oxidizer valves are similar with the exception of the gates, which are Type 410 stainless steel castings. These provide a better seal against the aluminum housing at the temperature of liquid oxygen. In addition, the gates are nickel plated to give better wear resistance between them and the seal which becomes hard at such cold temperatures.

*Subzero cooled and tempered, in this instance at 1050° F.

Uses for Nonmetallics

The elastic limit and sensitivity to impact of nonmetallics when exposed to liquid and gaseous oxygen are special criteria for these materials. Certain chloroprene and buna-N compounds are satisfactory in gaseous oxygen as static and dynamic seals at ambient temperature and as static seals in liquid oxygen. Fluo-

Fig. 3 — Bell Furnace Heats Combustion Chamber to 1900° F. Chamber, sealed in a retort, is brazed in 5 to 10 min.

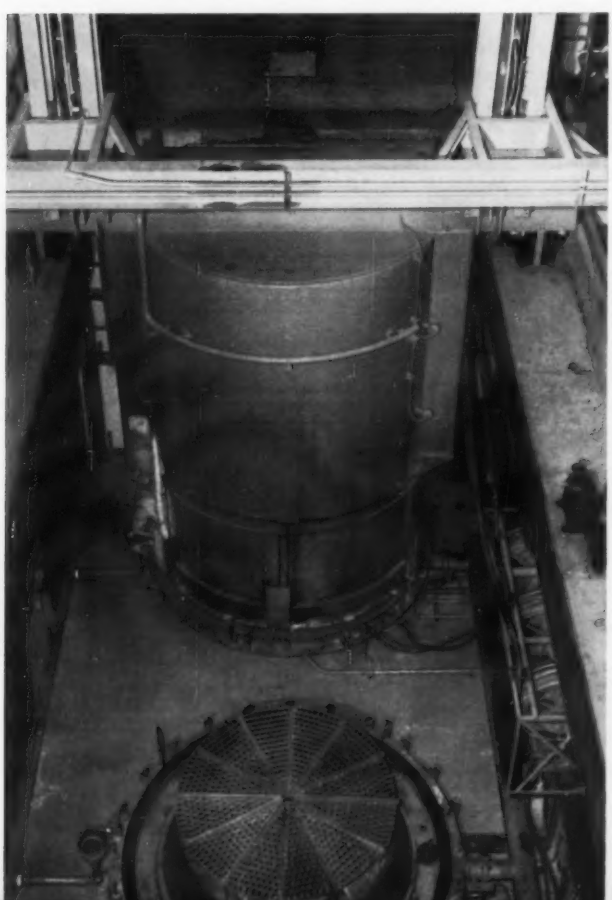
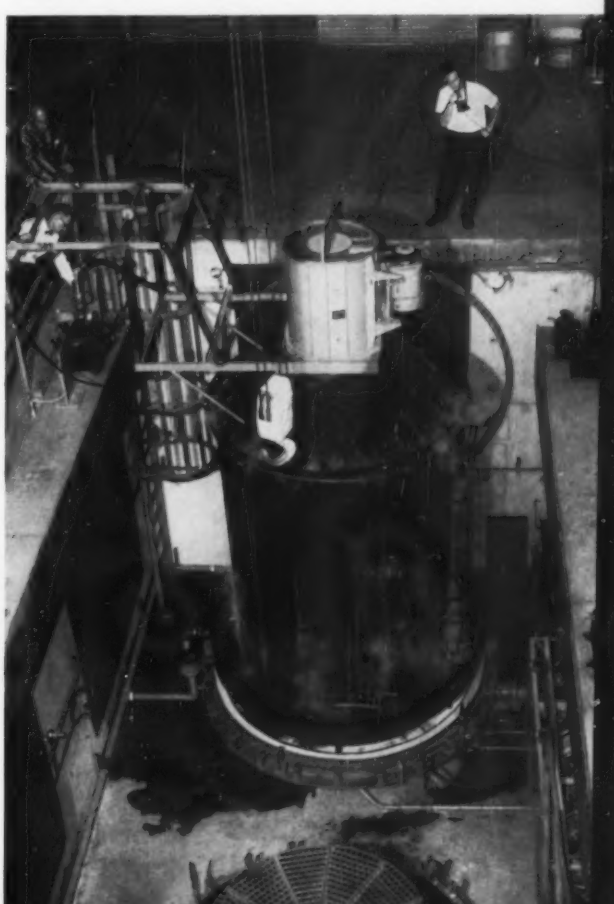


Fig. 4 — Retort, After Bell Furnace Has Been Removed, Is Cooled in Air or in This Water Cooled Hood



rosilicone has also been used with some success.

Halogenated paraffin oils with pour points as low as −100° F. can be used during assembly to lubricate static O-ring seals in liquid oxygen systems. These oils are not appropriate for lubrication of aluminum in a high shear application. Antiseize thread sealants of graphite in chlorinated organic carrier have been found suitable for use in liquid oxygen.

Tests indicate that in dynamic applications polychlorotrifluorethylene is satisfactory. Extensive compression molding of this material in sheets up to ½ in. thick followed by a rapid quench in cold water and a heat treatment yields the best combination of properties.

Perfluorinated polymer and orientated film of polyethylene teraphthalate were selected initially for static seals and gaskets in liquid oxygen. When filled with glass fibers to reduce cold flow, the perfluorinated polymer is superior to polychlorotrifluoroethylene for most cryogenic static seals.

Materials employed in conventional jet engine service are also useful in the fuel system of the Titan engine. Nylon (MIL-P-17091-B) and polychlorotrifluoroethylene are suitable for most dynamic applications.

Perfluorinated polymer can be employed for gaskets and static seals. Buna-N elastomers (MIL-P-5315) are suitable in both static and dynamic applications. The RP-1 fuel will lubricate dynamic seals during operation. Antiseize thread sealant used in the oxidizer system is also satisfactory for low-pressure use in the fuel system, but only for lubrication of the threads to permit disassembly. Where high pressure sealing is required, white lead must be specified.

Ablative Skirt Made From Nonmetallics

The ablative skirt for the second-stage engine of the Titan (Fig. 5) represents an important new application for nonmetallic materials in large liquid-fueled rocket engines.

First to be fabricated is the inner or ablative liner of the skirt. Asbestos tape, impregnated with phenolic resin, is wrapped as shown in

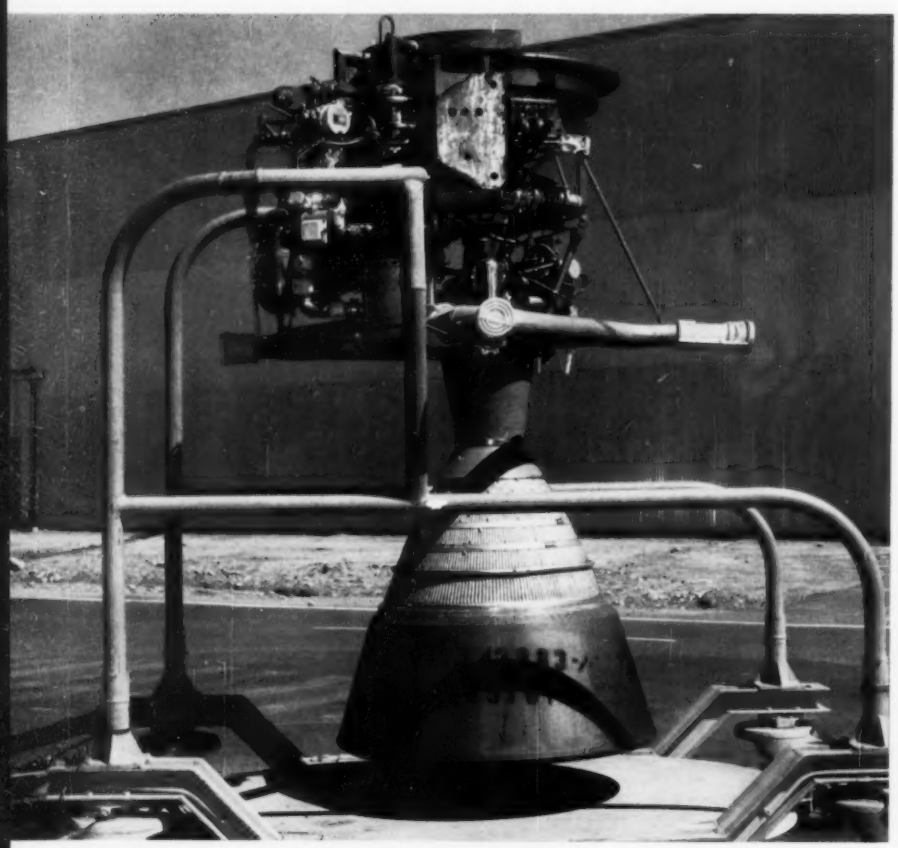


Fig. 5 — Second-Stage Engine for Titan ICBM Uses Nonmetallic Ablative Skirt Made up of Asbestos Tape Which Is Reinforced With Fiberglas Honeycomb

Fig. 6 on a mandrel at an angle of 45° to its surface. After being covered with glass tape and hair felt to permit escape of volatiles during curing, the wrapped mandrel is placed in a vacuum bag and pressure is reduced to 22 to 30 in. Hg.

Curing is carried out at about 350° F. in an autoclave maintained at 185 to 250 psig. Once cured, the liner is machined on the mandrel to specified dimensions. It is then reinforced with glass cloth impregnated with phenolic resin which is wrapped on the outside surface.

To attach the ablative skirt to the combustion chamber, it is equipped with a segmented flange of aluminum (6061-T 6) which is bonded to the forward edge of the liner with a liquid adhesive (MIL-A-8431, Class A). This bond is stiffened with asbestos-reinforced phenolic tape and glass cloth impregnated with phenolic resin applied over the flange segments and length of the liner. Curing at 320° F. takes about 1 hr.

Fiberglas Honeycomb Reinforcement

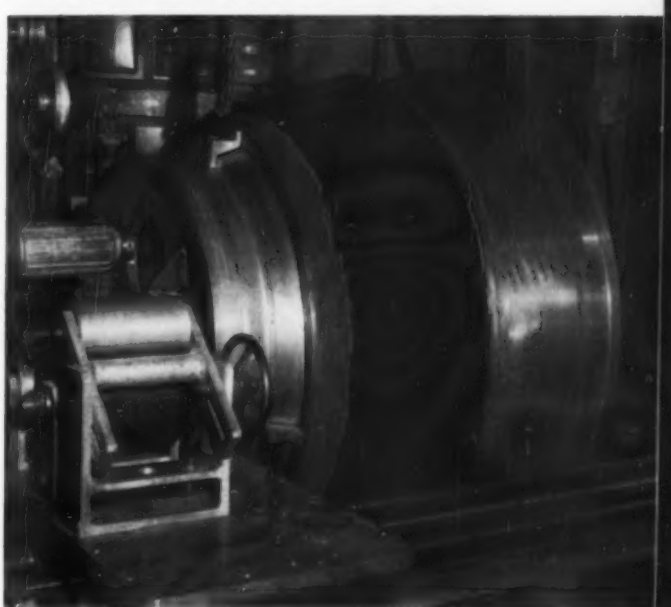
The next step is the application of the outer reinforcement for the skirt. A supported film of adhesive (MIL-A-8431, Class A) is applied to the surface of the liner to hold precut segments of cellular fiberglas (Fig. 7). This adhesive is then cured for 1 hr. at 300° F. and the assembly is trimmed and shaped. The aft edge of the cellular core is reinforced with epoxy compound and wrapped with glass tape. This is cured with heat lamps.

Final reinforcement consists of a supported film of adhesive that covers the cellular fiberglas core to which segments of glass cloth impregnated with phenolic resin are applied. Glass thread impregnated with epoxy is wrapped over the flange area. Final curing is carried out for 2 hr. at temperatures ranging from 220 to 280° F.

Thickness of the ablative liner is governed by the depth of ablation and char damage which occurs during a full-duration firing of the engine. This, in turn, is a function of pyrolytic decomposition and thermal diffusivity. In the pyrolytic decomposition of chrysotile asbestos, the kind used to make the inner liner, water representing about 14% of the material is released between 600 and 1400° F. At about 1490° F., the chrysotile structure changes to crystalline olivine, which subsequently melts at about 2800° F. These changes are, of course, endothermic and give asbestos an advantage over other materials for ablative liners.

Fig. 6 — Asbestos Tape, Impregnated With Phenolic Resin, Is Wound on a Mandrel at an Angle of 45° to Form the Inside Surface of Ablative Skirt. Windings are heated under pressure to 350° F. to cure the resin

Fig. 7 — Cellular Fiberglas Segments Reinforce the Ablative Skirt. They are attached to the cured asbestos windings, then ground to proper thickness after the adhesive is cured



Predicting Very-Short-Time Creep Behavior for Missiles

*By S. F. FREDERICK**

Conventional time-temperature parameters may be applied to very-short-time creep data; this will enable engineers to reduce the amount of testing required to establish minimum design values for creep. (Q3, 1-54)

DESIGNERS WHO MUST USE CREEP DATA have long recognized the need for ways to extrapolate such information to periods of longer time. To answer this demand, several parametric methods have been proposed in recent years. These systems generally assume an equivalence of time and temperature – thus, by conducting tests at temperatures higher than those proposed for service, the lower-temperature, longer-time behavior can be determined.

As an added feature, the parametric method can also be used to interpolate for temperatures not covered by test data; it is this latter use that is most attractive to the missile designer. However, it is not clear if previously proposed parameters would still apply for the short times of interest to him. Why? Because most of the parameters were derived in the region of steady creep where equilibrium conditions hold, the times are long, and the material is relatively stable. Also, since for many missile applications the allowable creep strains may be small (around 0.2%) and the times short (a few seconds), the transient (primary) creep region must be considered. In addition, the temperatures may be high enough to make the alloy metallurgically unstable. All of these factors point out the need to determine whether available parameters, such as those given in the box below, would be valid in predicting creep which occurs during very short times.

Creep Parameters

Larson-Miller	$P = T(\log t + C)$
Dorn	$\theta = te^{\frac{-\Delta H}{RT}}$
Manson-Haferd	$\psi = \frac{T_1 - T_a}{\log t - \log t_a}$
Graham-Walles	$\phi = t(T' - T)^A$

t = time
T = Temperature in absolute units
T_1 = Temperature in °F. or °C.
C, ΔH, T_a, t_a, T' = Material constants (obtained from test data)
$A = 20$
R = Gas constant

Four Parameters Used

In our work four different parameters were evaluated with very-short-time creep data obtained in our laboratories. We used digital computers to fit the data and evaluate the constants for Larson-Miller, Dorn, and Manson-Haferd parameters, using statistical methods presented by Manson and Mendelson for the job.† Evaluation of the Graham-Walles constant was done graphically. Figures 1 to 4 show the results. They verify the suitability of these parameters for this type of data, and also indicate that any of the parameters investigated correlate the information equally well.

It should be noted that the examples shown used test results that varied consistently with respect to stress. When we tried to analyze data

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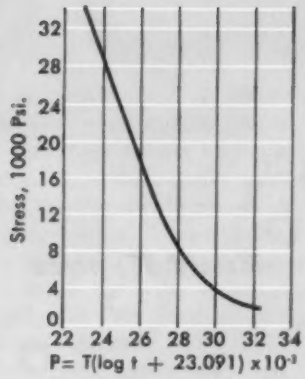


Fig. 1 – Larson-Miller Curve for Alclad 2024-T 81. For this curve, temperatures range from 500 to 750° F. Times range from 2 to 800 sec. for all illustrated curves, and the parameter units (again for all curves) are "seconds" for time and "degrees Rankine" for temperature

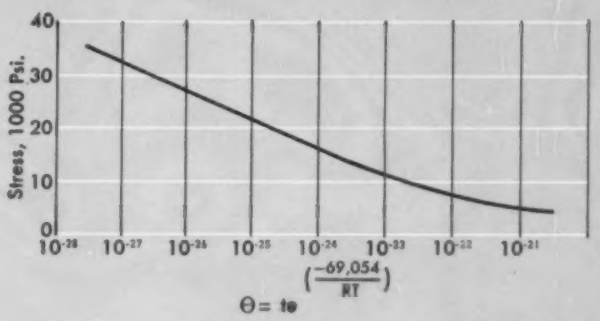


Fig. 2 – Dorn Curve for Alclad 2024-T 81. Temperature range: 500 to 750° F.

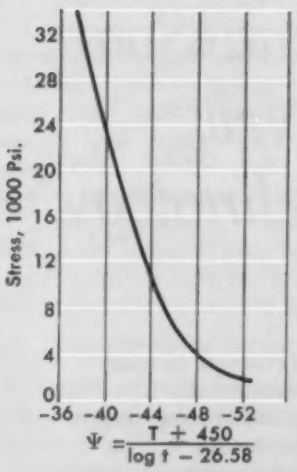
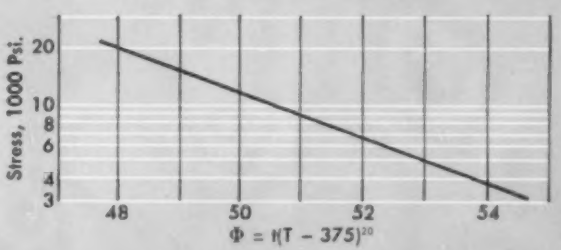


Fig. 3 – Manson-Haferd Curve for Alclad 2024-T 81. Temperature range: 500 to 750° F.

Fig. 4 – Graham-Walles Curve for Alclad 2024-T 81. Temperature range: 600 to 750° F.



for 4340 at temperatures spanning the tempering temperature, we found essentially no correlation. This is likely to occur when changes in metallurgical structure and rate-controlling mechanisms combine to give inconsistent properties. Since this results in a variable parameter "constant", there is obviously a need for caution in extrapolating to temperatures not covered by tests.

Parametric correlations can also be used to establish minimum design values for creep. For example, if a given parameter can be considered to represent the data, all the data can be grouped into a single lot and treated statistically to give minimum values at the desired confidence level. Such an approach can materially reduce the amount of testing required without sacrificing reliability.

Before applying the information, we should make one decision. Should the variation in stress or the parameter value be considered dependent? A preliminary examination indicates the parameter value should be so selected because, until more information is available, a normal distribution with common variance has been assumed. The use of stress or a function of stress gives excessively conservative values at either high or low stresses, probably because the assumption of common variance does not hold.

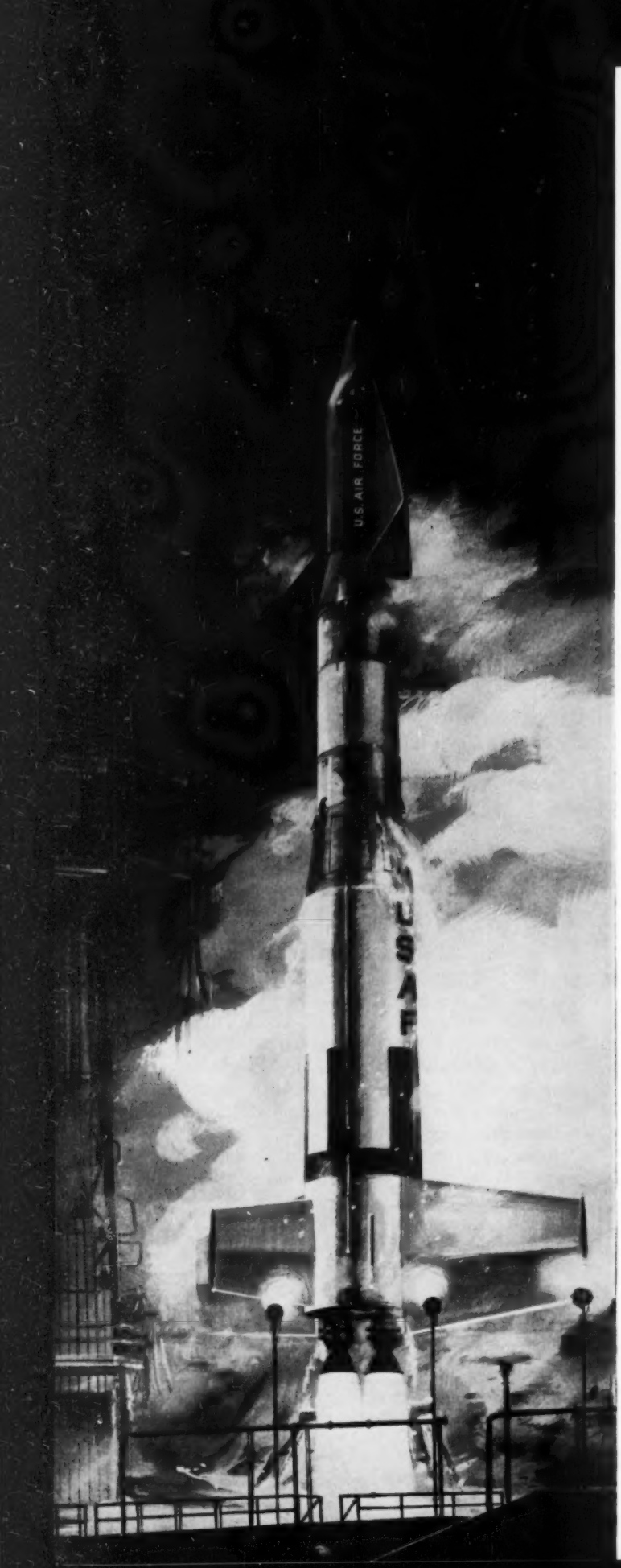
†"A Time-Temperature Relationship for Rupture and Creep Stress", by F. R. Larson and J. Miller, *Transactions* A.S.M.E., Vol. 74, No. 5, July 1952, p. 765-771.

"Correlations of Rupture Data for Metals at Elevated Temperatures", by R. L. Orr, O. D. Sherby, and J. E. Dorn, *Transactions* A.S.M., Vol. 46, 1954, p. 113-128.

"A Linear Time-Temperature Relation for Extrapolation of Creep and Stress-Rupture Data", by S. S. Manson and A. M. Haferd, N.A.C.A. TN 2890, 1953.

"Relationships Between Long and Short-Time Creep and Tensile Properties of a Commercial Alloy", by A. Graham and K. F. A. Walles, *Journal* of the Iron and Steel Institute, Vol. 179, Part 2, February 1955, p. 105-120.

"Optimization of Parametric Constants for Creep-Rupture Data by Means of Least Squares", by S. S. Manson and A. Mendelson, N.A.S.A. Memo 3-10-59E, March 1959.



Staff Report

Dyna-Soar . . . a New Technology

The environment of space and re-entry create severe material requirements. In the fabrication of winged re-entry vehicles, engineers must apply revolutionary concepts to meet the requirements of this emergent technology. (T24e, L-general, 17-57; SGA-h, EG-d)

THE DYNA-SOAR GLIDER is designed to orbit the earth and re-enter the atmosphere for a conventional landing. It differs from Project Mercury in that the Dyna-Soar will be under control of the pilot while the Mercury astronaut will be primarily a passenger. Figure 1 shows a concept of a Dyna-Soar type glider leaving the ground

Fig. 1 – The Dyna-Soar Glider Will Be Boosted Into Space by a Modified Titan Intercontinental Ballistic Missile, According to This Concept by the Boeing Airplane Co., Prime Contractor for the Program. The objective of the system is to send manned vehicles into space, and through controlled re-entry bring them back to earth

under power from a Titan ballistic missile. The first stage engine propels the Dyna-Soar to the upper fringes of the atmosphere. The second stage then ignites and continues accelerating the airplane to near-orbital velocity. Following this, the glider separates from the second stage engine using an engine on the glider to get away from the empty hardware and to supply the last burst of energy to send the vehicle into orbit.

When the glider goes into orbit, it will be traveling 18,000 mph. The problem which engineers must solve is to slow it down after the required number of orbital trips are completed and to land it like an airplane, giving the pilot control of the flight. Throughout the re-entry, materials used to construct the nose, leading edges and skin of the glider reach red and white-hot temperatures as illustrated in Fig. 2. The glider must remain in this red-hot flight condition for a period of minutes to get rid of its tremendous energy, instead of seconds which are involved in some of our space probes.

Fig. 2 — Leading Edges of the Space Glider Will Glow From the Heat Created by the Friction of the Vehicle Passing into the Atmosphere. The environment of space and re-entry creates the most severe material requirements. Heating rates for the winged glider are of such magnitude that refractory metals can be efficiently utilized

Basic Design Must Be Simple

A complex pattern of flow and shock waves develops around the glider as the highly heated air moves to get out of the way of the airplane. Furthermore, any fins, antennas or rough edges which stick out of the glider are subjected to hot treatment by this super hot air plasma. On a meteor, for instance, the protruding parts and some of the body simply boil and vaporize off leaving a trail of sparks in the sky. Thus, part of the job of engineers is to design a shape that will fly at these tremendous speeds, but which leaves nothing sticking out in the airflow to get burned off. This means that the shape of the glider must be simple.

But engineers are faced with the equally difficult job of selecting materials to use in structures of winged re-entry vehicles such as the Dyna-Soar. The environment of space and re-entry create the most severe material requirements. Heating rates and related temperatures are of such magnitude that the refractory metals can be efficiently utilized.

Refractory Metals Versus Superalloys

Actually, the designer of winged re-entry vehicles has the alternative of using refractory metals — tungsten, columbium, molybdenum and tantalum — in high-temperature areas, recognizing the limitations of our present technology with these metals, or he can utilize methods of cooling that keep temperatures within limits of superalloys such as René 41. A high-melting-point material (for example, tungsten, tantalum or ceramics) may be required for the stagnation area on a nose cap, since re-entry temperatures approach 5000° F. Lithium cooling could be used to reduce the temperature to that permissible for a lower-melting-point, lighter-weight refractory metal or a nickel-base superalloy. In this instance, strength requirement is minor — temperature is the main concern.

The leading edge is the hottest area for the primary load-carrying structure. Alloys of columbium or molybdenum are favored for these components since the operation range of 3000 to 3800° F. is such that these materials will provide the lightest, most efficient structure. Molybdenum alloyed with 0.5% titanium and F-48 alloy of columbium (see *Metal Progress*, June 1960, p. 73) are promising panel materials. Recrystallization of refractory metals under operating conditions is a problem which requires a solution to utilize the maximum strength capability of these metals.

Coatings to Protect Refractory Metals

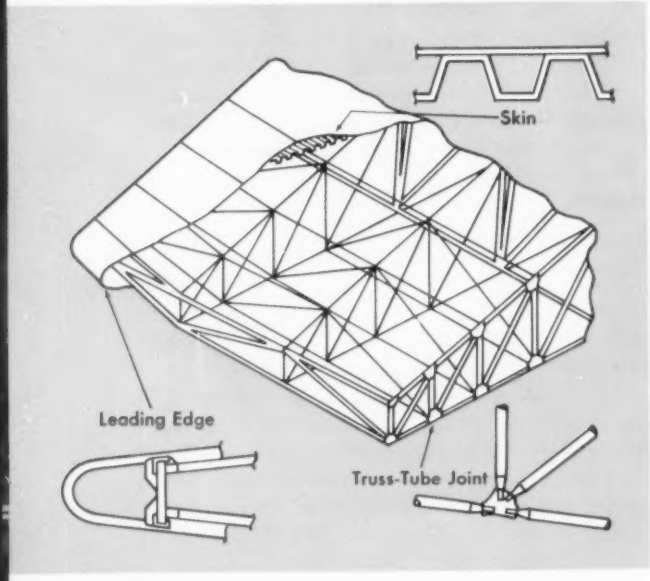
Another critical problem in the application of the refractory metals at high temperatures is lack of oxidation resistance. Columbium and tantalum exhibit the best oxidation resistance and molybdenum the worst. However, the fact that the oxidation rate of columbium is much better than that of molybdenum is not significant because the high temperatures of re-entry exceed the application range of all four of the refractory metals. Therefore, they all present the problem of coating development.

After more than two years of work on the problem, engineers at Boeing Airplane Co. have recently devised a coating and method of application which shows great promise. Called the DiSil coating, the process is based on inducing silicon into the surface of molybdenum, probably to produce a modified molybdenum disilicide coating which is integral with the basis metal.

The DiSil coating on molybdenum is dark, hard, and has good erosion and shock resistance. The coating remains stable at 3200° F. and higher and weighs only 0.01 lb. per sq.ft. Tests of DiSil coatings on a columbium alloy have given good results.

In developing refractory metal coatings, it is extremely important to consider the emissivity of the coating and the anticipated heat rates to evaluate the effects on temperature of variations in emissivity. Cold temperatures will be encountered when the vehicle is in orbit and passes around the dark side of the earth. While no loads will be encountered at this temperature, the metal and coating must stand up to the below zero environment without deterioration of its properties.

Fig. 3 – Refractory Metals and High-Temperature Alloys Must Be Formed Into Various Shapes for the Structure of a Space Glider. The diagram below, prepared by Edwin C. Czarnecki, Boeing Airplane Co., shows a typical wing structure with representative shapes for the leading edge, interior truss, and skin panels. Pinned trusses and flexible panel connections are an important design concept to prevent the creation of large thermal stresses



Metals Must Be Formed

The structural design of a re-entry glider requires that metals be formed into various shapes for the leading edge, interior truss, and skin panels (Fig. 3). Due to the light flight loads, minimum gage material will be specified in the majority of panels. A typical panel might be made up of 0.008 in. face sheet with 0.010 in. corrugations utilizing an 18-in. corrugation span. Flexible connections are employed which allow the panel to expand and rotate with increasing temperature. This prevents major thermal loads, since the only thermal load is that developed by a nonuniform temperature gradient through the depth of a corrugation. This permits most of the strength of the material to be available for the flight loads. (Additional information on forming close-tolerance corrugations is given on p. 132.)

While it is desirable to utilize refractory metals for minimum-weight structures in re-entry vehicles, the designer can avoid them if their technology is not sufficiently developed in the time period required, at the expense of slight increase in total weight of the system. The primary structure can be designed for ablation cooling, or it can be constructed to utilize principles of insulation and water cooling or uninsulated radiation cooling. With ablation cooling, the primary structure can be composed of superalloys. The insulated or insulated and water cooled concept could use a superalloy load-carrying structure but requires a metal heat shield for the exterior cover. An uninsulated radiation cooled type would use refractory metal alloys for the load-carrying structure.

There are other fields of new technology which must be understood to enable a typical re-entry glider, such as Dyna-Soar, to fly safely. A few examples: air conditioning equipment inside a red-hot airplane, an auxiliary power plant within the glider to provide electrical and hydraulic power for the controls and equipment, and a radio system to enable communication with the ground while the glider is operating under difficult conditions. Perhaps one of the biggest problems comes under the heading "reliability" which means that the structural design and all the equipment must work without fail under the extreme conditions to which it is subjected.

Producing for the New Technologies

Brazing Missile and Electronic Components in Dry Hydrogen—I

*By H. E. LEWIS**

Because dry hydrogen is highly reducing to most oxides at high temperature, it makes an excellent brazing atmosphere. But successful brazing in dry hydrogen requires careful consideration of many factors. Part I of this article discusses factors such as surface finish, fixtures and types of furnaces needed to obtain good results. Next month, atmosphere and temperature control will be covered. (K8; SS, SGA-h)

HYDROGEN BRAZING was first used as a production process some 30 years ago. Its adoption by industry was slow at first because of the great danger of explosion, the unavailability of commercial hydrogen and its cost. These disadvantages have generally been overcome and the use of the process has greatly increased.

With the acceleration of missile and electronic requirements for joining stainless steels, heat resisting alloys and other metals, hydrogen which is deoxidized and dried to a very low dew point has proved to be an excellent atmosphere for reducing the oxides that prevent wetting of base metals by brazing alloys.

Oxidation problems are completely eliminated in dry-hydrogen brazing except for those metals containing titanium and aluminum. These metals require special preparation for brazing. The elimination of oxides means the elimination of fluxes to reduce them. There are, therefore, no entrapped fluxes left in the joints, no corrosion problems due to residual flux, and no fluxes in areas that might be exposed to vacuum in a vacuum tube assembly. Because parts come out of the furnace clean and bright, post cleaning is not necessary.

Because requirements for brazing complicated assemblies of a wide range of metals and alloys have increased, it is increasingly important that the brazing engineer be thoroughly familiar with all of the factors outlined.

Materials Pose Many Problems

When presented with a joining problem, the first question should concern the materials of the components. Many a braze has been ruined because of lack of exact information about the materials. If stainless, what type? Does it contain titanium or aluminum? These are troublesome. And copper? Is it oxygen-free? If copper is not oxygen-free, the components will

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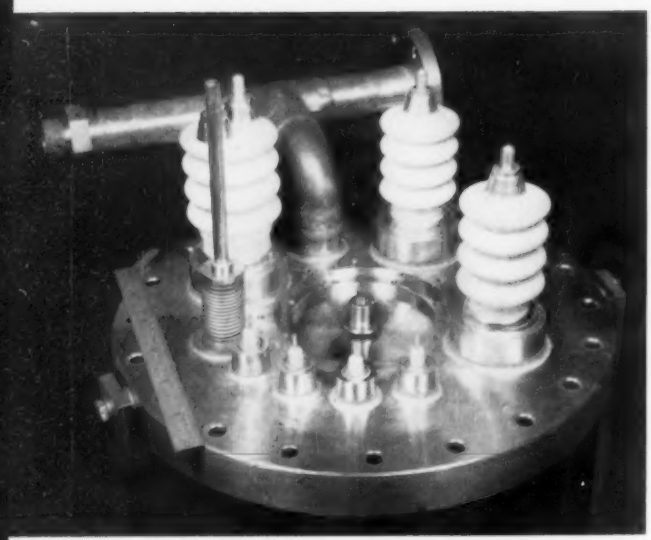
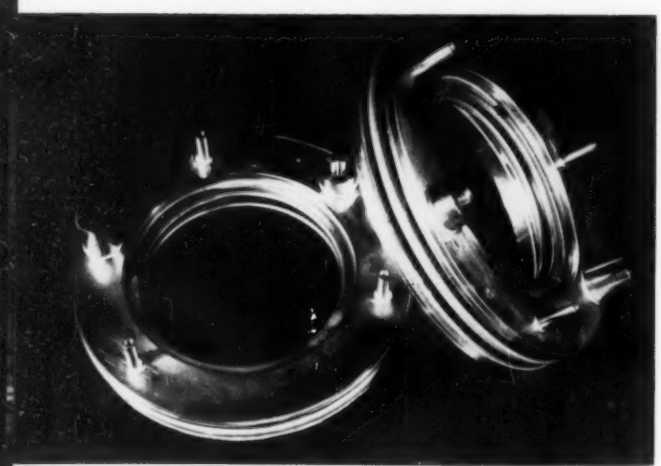


Fig. 1 – This Component for High-Vacuum System Was Brazed in Dry Hydrogen. It is a feed-through assembly made by joining Type 304 stainless steel, Kovar, a ceramic and oxygen-free copper. Component was brazed in three steps, each at a lower temperature, by induction heating in a bell jar filled with dry hydrogen. Three different precious-metal filler alloys (Au-Cu-Ni, Au-Ni, Au-Cu-In) were required to effect this three-step braze

be ruined if the braze is made at high temperature in hydrogen.

What is the microstructure of the metals?

Fig. 2 – Complex Double Bellows Assembly of Type 304 Stainless Steel. Parts were brazed in dry hydrogen (dew point: −80° F.) in two steps with Au-Cu-Ni alloy, then with Au-Ni alloy



What prior treatments have they had? Are they stressed by cold work or machining? Or have these stresses, which can cause warping, been relieved?

Surface Finish – What is the surface condition of the components? Have all mill surfaces been removed? Have the parts been pickled or blasted? If pickled, have the surfaces been cleaned of the sooty residue that sometimes results? If blasted, what was used as the blasting material? Aluminum oxide grit is sometimes used to discourage wetting in selected areas. Steel and silicon carbide grit have been used to promote wetting. If machined or ground, what is the surface roughness? A relatively rough surface aids brazing; a finely ground or burnished surface generally does not wet readily.

In considering the materials of an assembly, thought must be given to their microstructure after brazing because it affects strength and other properties. Many materials will be softened. Some will be hardened.

Know Properties of Brazing Alloys

The next major factor involves the brazing alloy or alloys to use. What are the strength requirements and what are the operating conditions? Is more than one brazing alloy required? Perhaps all joints can be brazed at one time, but often the final assembly is more easily made by a series of brazes, each succeeding one at a lower temperature (Fig. 1 and 2). It is important to have exact information as to the melt, flow and brazing temperatures of the alloys. How well do the alloys wet the component metals and what are the alloying characteristics of the brazing metal? Alloying is likely to cause erosion and it may raise the flow point, thus stopping penetration of the joint. Consideration must also be given to the available forms of the alloy and how it can be placed at the joints.

Fixtures – Joint design must take into consideration required joint strength, the flow of brazing alloy through the joint, the placement of the alloy so that it will pull into the joint and the means of holding the parts together and maintaining their orientation during brazing. The importance of holding the parts together is obvious, but frequently overlooked. Whenever possible, shoulders or locking devices should be used to make the assembly self-locating. Fixtures for holding the assembly together and support for holding it during braz-

ing are part of the design problem. Proper support during brazing is also imperative.

Clearance – In designing any brazing assembly, the clearance provided for the brazing alloy must be considered from the standpoint of the alloy to be used – how it penetrates the joint and the optimum clearance for maximum strength.

Maintaining proper clearance is not always easy, even when the need for it is recognized. Very close control of the sizes of mating parts adds considerably to production costs. On elaborate, expensive assemblies, it is usually more important to spend the money to obtain the proper fits than to risk spoiling the entire assembly.

If close tolerances cannot be met in practice, the use of knurls, shims or powdered filler metals can sometimes be used to narrow gaps that would otherwise be too large. These corrective methods must be carefully considered before being used.

Expansion Affects Design

An important consideration in the over-all design is the differential expansion of the components which results from the use of dissimilar metals (Fig. 3) and from differential heating and cooling. When dissimilar metals are to be brazed, the clearance in the joint at brazing temperature will depend on the difference in their coefficients of expansion. Dissimilar metals used in the same plane may also distort the assembly.

Heating and Cooling Rates – Even with components of the same metal or metals of approximately the same coefficient of expansion, dislocation or distortion of the assembly can result if the heating and cooling rates of different parts of the assembly are not uniform. Thin sections may reach temperature ahead of thick sections, or shielded areas will lag behind unshielded areas. Differential heating can push an assembly apart. Differential cooling can be just as damaging if the alloy solidifies while the components are at widely different temperatures.

Furnace and Induction Heating

For dry-hydrogen brazing, the choice of heating method is between furnace and induction heating. Most assemblies require one of the wide variety of furnaces which are available. In addition to special continuous or semicontinuous types, there are a number of retort furnaces. The retorts are sometimes sand-sealed, gasketed, or welded (Fig. 4). They are heated by bell, pit, elevator or box furnaces.

In addition to temperature range, temperature control and uniformity and method of maintaining purity of the atmosphere, the method of applying heat can also be important. One should also consider whether or not the brazing assembly might be moved or jarred while the brazing alloy is molten or is solidifying. Such movement can cause failure of the braze.

Brazing Stainless – Sometimes even complicated stainless steel assemblies can be induction brazed in dry hydrogen without flux. To make induction brazing possible, a sealed enclosure which can be purged with dry hydrogen must be provided around the braze area or around the complete assembly. Also, means of purging

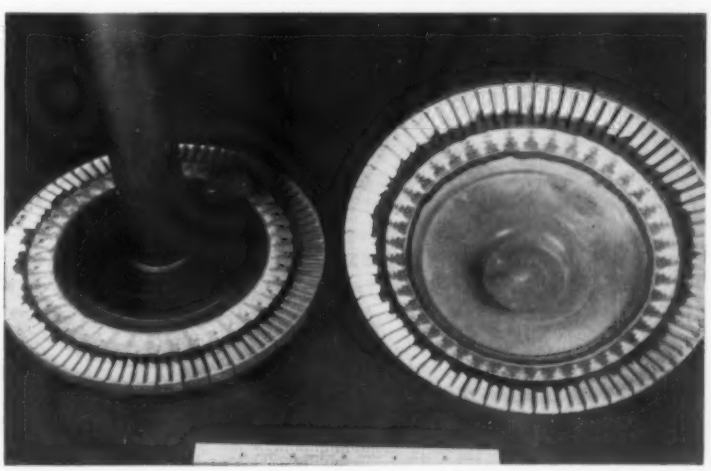


Fig. 3 – Rotor Assembly Was Fabricated by Brazing Dissimilar High-Temperature Nickel-Base Alloys in Dry Hydrogen. Without good design, differential expansion of dissimilar alloys can lead to distortion and unpredictable joint clearances

Fig. 4 – Furnace Used for Brazing Parts in Dry Hydrogen. Welded steel retort gives positive seal around parts thus preventing leaks. Furnace this size can handle parts up to 72 in. in diameter. Fixturing, which varies with the configuration of the part, is done with hydrogen-fired ceramics, metals or graphite. During the brazing cycle, the actual temperature of the parts is automatically recorded. Flow meters in the base of each retort control the flow of hydrogen

any cavities or any internal areas must be provided. An induction generator is used of a suitable frequency and capacity as determined by the sections of the mating parts in the braze area and by the temperature required. The sections must be such that localized heating will not occur and damage the components.

Dew Point Governs Equilibrium Point

In the brazing of stainless steels and heat resisting alloys in hydrogen, it is important to be familiar with metal-metal oxide equilibriums.* This relates the dew point of the hydrogen atmosphere to the temperatures at which various metals are in equilibrium with their respective oxides. Under equilibrium conditions, the rate of oxidation of the metal by water vapor is exactly equal to the rate of reduction of the oxide by hydrogen. If the dew point should increase while the temperature remains unchanged, the equilibrium is disturbed and water vapor starts to oxidize the metal until equilibrium is restored. Conversely, by lowering the dew point, hydrogen, being in excess, will reduce the oxide in order to re-establish equilibrium.

Reduce Oxides – In brazing, the reduction of oxides is of primary importance. Stainless parts that appear chemically clean may still have surface oxides that will prevent brazing, particularly at lower temperatures. To reduce oxides already present, either a higher temperature or a lower dew point than indicated by equilibrium data must be used.

It must be remembered that the dew point to be considered is that surrounding the parts being brazed. It cannot be assumed that it is the same as the inlet or outlet dew point. When brazing is performed in a properly sealed and purged retort on parts that are free of oxides and with no contamination from the retort, fixtures or other source, it will be successful if the inlet dew point is slightly lower than that called for from the equilibrium data. These equilibrium data are of little *(Continued on p. 162)*

*A graphical representation of some equilibrium relationships and an excellent discussion of the subject is given in an article by W. H. Chang in the *Welding Research Supplement*, December 1956.

Problems of Machining Space-Age Metals

*By L. A. HAUSER and M. C. METZGER**

If full benefit is to be derived from their potential strength, the superalloys and ultra-high-strength steels must frequently be shaped while in the fully heat treated condition. However, as hardness increases, machining becomes progressively more difficult. This article offers suggestions on machining alloys with hardnesses in some instances over Rockwell C-50. (G17, AY, Ni-b, Co-b, TS, SS, SGA-h)

As is well known by now, space-age materials are difficult to fabricate. This is especially true of the ultra-high-strength steels which have been heat treated to Rockwell C-50 and above and many of the superalloys, which are difficult to machine regardless of the hardness. (Figure 1 shows the relation between strength and hardness for three high-strength alloys.) Those who may be required to fabricate these space-age metals should consider some of the problems that will be met along with possible methods to lessen their severity.

Take, for example, H-11 or A.I.S.I. 4340. After hardening and tempering the steel, it is usually necessary to do some machining or grinding to meet decarburization control requirements and close tolerances for dimensional accuracy. It is at this point that the machining problems arise. Cutting any steel at Rockwell C-50 or higher is difficult even for external surfaces, and it becomes still more troublesome for internal boring, tapping and end milling. This is particularly true if these operations must be performed from an unfavorable angle or where there are small radii and deep pockets.

In itself, the actual hardness is extremely important since it can have a significant effect on tool life. Although it is well recognized that material over Rockwell C-50 will be considerably more difficult to machine than the same material at a lower hardness, the effect of each point of Rockwell C hardness *above* 50 becomes of increasing importance in machining operations.

Figure 2, which illustrates the effect of hardness on A.I.S.I. 4340 on both end milling and drilling operations, shows that hardnesses over Rockwell C-52 produce the utmost machining difficulty. Though similar specific data are not available for some of the other steels, there is no doubt that the same effect will be noted in this hardness range.

Although there is little likelihood that machining in the heat treated condition can be eliminated, designers should consider the advantages of machining closer to the finish size while the material is still in the annealed condition. Then, only a minimum amount of material would need to be removed to eliminate decarburization and to correct any warping caused by heat treatment. For many years, this practice has been the standard in producing die casting dies, forging dies, blanking dies and many types of cutting tools. Further experience with aircraft components will probably indicate quite accurately the minimum amount of extra material that the part must have to compensate for movement (in warping) and decarburization;

*Metallurgical Engineers, Technical Service, Universal-Cyclops Steel Corp., Bridgeville, Pa.

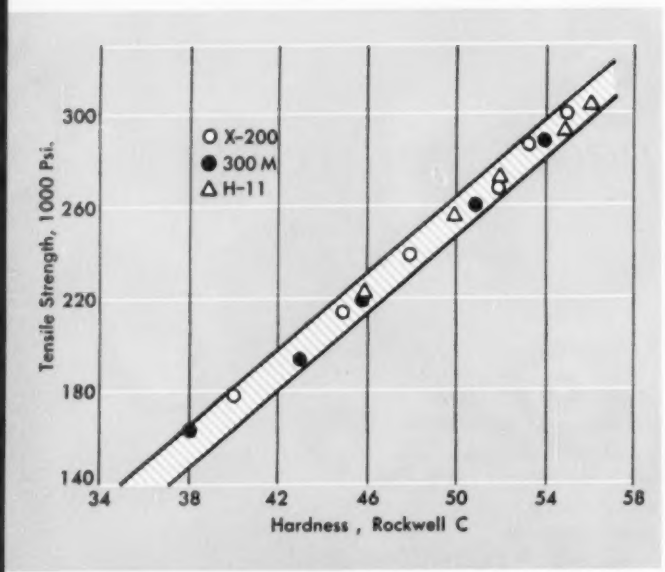


Fig. 1 – Hardness-Tensile Strength Relationships of Three High-Strength Alloys. These and other similar materials are very difficult to machine at the desired strength levels

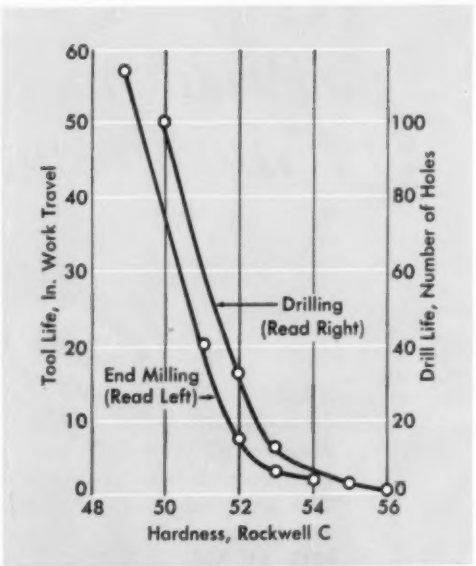


Fig. 2 – How Increasing Hardnesses Affect the Life of High Speed Steel Tools. As is evident in these tests on 4340, each extra Rockwell point above C-50 makes both end milling and drilling much more difficult

this will help reduce the amount of metal that must be removed at Rockwell C-50 or higher.

Rigidity Is Essential

To machine the high-strength steels, the work piece, the tool holder and the machine tool itself must be as rigid as possible. Furthermore, vibrations resulting from the machining operation or from any external source should be held to a minimum. Also, the machine must be adequately powered to reduce chatter and insure the desired penetration of the tool's cutting edge.

There is room for considerable discussion in the selection of the proper tool material for the particular operation. (In many instances, in fact, there is *no* general agreement.) For turning and most milling operations, carbides and ceramics seem to be generally preferred.

High speed steels have also been successful in these operations, although tool life is usually very short. For tapping, drilling and some end milling operations, high speed steel has given good results. When there is excessive frictional heat, the high speed steel with the most heat resistance should be used. For these situations, best results have been obtained with the M-33, M-34, T-5 and T-15 types.

After selecting the tool material, the proper speed, feed and tool geometry should be chosen. Chip load, or feed, must be such that the cutter teeth penetrate under the surface layer. If not, the surface will work harden, and the resulting high frictional heat and vibration will cause excessive tool wear and deterioration of the surface. Tools must be ground to very close tolerances to insure uniform loading.

Where it is possible to grind the finished part after heat treatment, careful control is required to avoid grinding cracks in these materials at high hardness levels (even though the greater resistance to tempering of H-11 enables grinding operations to be used with less likelihood of softening the surface). Furthermore, parts should be stress-relieved after grinding.

Superalloys Offer Problems, Too

Superalloys, often used in gas turbine jet engines where operating temperatures require heat and corrosion resistant metals, are also difficult to machine. In their softest condition, which is produced by either annealing or solution treating, they are "gummy". This condition causes the tool to heat up very rapidly. Material builds up on the cutting edge of the tool, and when this build-up edge shears off,

Machining High-Temperature, High-Strength Alloys

- Machine tools should be rigid, modern and as "overpowered" as possible.
- Hold both the work and the tool rigid.
- Tools should be kept sharp at all times. Hone the cutting edge slightly.
- Carbide tools are often mandatory.
- Generally, tools should be ground with a zero to slightly positive back rake and positive rake.
- Keep tool "overhang" to a minimum to help maintain rigidity.
- Heavy sulphur-base or sulphur-chlorinated lubricants are generally preferred.
- The depth of cut should be as heavy as possible to avoid "glazing". Feeds and speeds usually must be lower than with conventional metals.
- Drilling is the most difficult machining operation – turning and facing are the easiest.
- Last but not least: Have patience, don't expect miracles – at least not immediately.

part of the cutting edge also chips away. Ultimately, the tool fails. If extreme care is not exercised, these grades will work harden severely, causing the tool to glaze over, or burnish the part being cut.

Although "gummy", these grades are quite strong, requiring higher horsepower for machining than conventional types of steel. Those grades that can be heat treated are somewhat easier to machine because of their lower work hardening tendencies. However, because they reach hardnesses of Rockwell C-35 and higher, they have high shear strengths, are abrasive in nature, and present major machining problems. Iron-base alloys, which have an over-all machinability rating of 30 to 45%, are designated as satisfactory. In contrast, the nickel and cobalt-base groups (rated from 10 to 15%) are much more difficult to machine. In the iron-base toolsteel group, the martensitic steels, which are subsequently hardened and tempered (H-11 is a good example), machine best in the annealed condition. Good machining characteristics can also be obtained by following the annealing treatment with a definite amount of cold drawing. This controlled amount of cold work increases hardnesses somewhat, improving response to machining. The hardened and tempered condition has the poorest machinability; it will vary with the tempering temperature. Hardnesses range from C-25 to 45.

For the "transformed and tempered"* type of martensitic steels, the equalized and overtempered condition provides best machinability. Average machinability, attained by full heat treatment (transformed and tempered), can be further improved by overtempering. In the annealed condition, the steel is soft, and great care must be exercised to prevent any cold work which would result in transformation to hard martensite. Such transformation would result in erratic machinability and poor tool life.

For best machining, the work hardened, iron-base austenitic alloys (19-9 DL, a stainless steel) are annealed, cold drawn a controlled amount, and stress-relieved. Next best is the warm worked and stress-relieved condition. Average machinability can also be attained by an intermediate annealing treatment. In its softest condition, fully annealed, this type of alloy has its poorest machining characteristics.

The precipitation hardening iron-base alloys, such as A-286, are best machined after being solution treated and cold drawn to a given degree. Solution treating, followed by overaging, results in average machinability. If it is not feasible to overage, the standard solution treatment and aging cycle will give fairly satisfactory results. Because of "gumminess" and work hardening tendencies, the solution-treated condition is the poorest for this type of alloy.

For the austenitic nickel-base materials which do not harden by heat treatment, the annealed condition provides the best over-all machinability. Some users have found that a controlled percentage of cold work following the annealing treatment will give good machining characteristics. The hot rolled condition – that is, the condition of the material as it comes off the rolling mill and cools to room temperature – is poorest for machining.

Those nickel-base austenitic materials which

*"Transformed and tempered" steels are those which harden by transformation rather than by conventional quenching in oil or water. The so-called precipitation hardening stainless steels such as AM 350 and AM 355 are examples of this type. The "equalize" treatment (1450° F. for 3 hr. – air cool) precipitates alloy carbides and permits transformation of austenite to martensite. The "overtemper" treatment (1050° F. for 3 hr. – air cool) softens the martensite.

Need Help in Machining Difficult Alloys?

The Data Sheet (p. 100-B) on machining A-286 is the first in a series which will present the results of studies on machining characteristics in turning, milling, drilling and tapping high-strength heat resistant alloys. Subsequent Data Sheets will be devoted to machining AM 350, 6 Al, 4 V titanium, A.I.S.I. 410, Udimet 500, Inconel 700, HS-25, A.I.S.I. 4340 and H-11 type hot work die steels.

Information in the Data Sheets was developed through the U. S. Air Force. Machinability studies were sponsored by the AMC Aeronautical Systems Center, Manufacturing and Materials Technology Division, Wright-Patterson Air Force Base, Ohio. These studies, now in their fifth phase, were started in 1949 and were designed to solve machining problems facing the aircraft and other industries. Emphasis has been placed on studies of difficult-to-machine alloys. The plan has been to develop data for practical machining before new alloys are used extensively in production applications.

Phases 1, 2, 3 and 4 of this program were accomplished under a prime contract to Curtiss-Wright Corp. with Metcut Research Associates, Inc., as the major subcontractor performing the machinability testing. All four phases were concluded with a final report, U. S. Air Force Machinability Report, Vol. 1, 2, 3 and 4. Volume 1, published in 1950, deals with jet engine alloys. Volume 2, published in 1951, is devoted primarily to the machinability of 12 steels in various microstructural forms and at different hardness levels. Volume 3, published in 1954, covered titanium alloys. Volume 4, which was published late in 1960, is devoted to high-strength thermal resistant materials. Volumes 3 and 4 are available from Curtiss-Wright Corp., Wood-Ridge, N.J. Phase 5, now under way, will be concerned with refractory materials with Metcut Research Associates, Inc., serving as the prime contractor.

The machining data presented in the Air Force Machinability Reports and in the Data Sheets in this and subsequent issues of *Metal Progress* were obtained by running tool life tests rather than by abbreviated or simulated tests. While this method is more time consuming, it leads to accurate data which are reproducible in the shop. The reproducibility is enhanced by the fact that production-type machine tools and tooling was used in conducting the machinability tests. The cutting conditions shown provide practical starting points in setting up machining operations for the alloys involved.

Metal Progress acknowledges the assistance of Robert T. Jameson of AMC Aeronautical Systems Center and John Maranchik of Metcut Research Associates, Inc., in preparing this background information and in making these Data Sheets available.

can be precipitation hardened (Waspaloy, for example) exhibit best machinability when they are solution treated and partially aged. When such a heat treating cycle is not feasible, these grades can be machined, although with greater difficulty, after a full aging treatment following the solution treatment. Machining quality also falls off in the annealed or solution-treated condition primarily because the materials are "gummier" and have high work hardening tendencies. When the alloys are used in this condition, tools must be kept sharp at all times and the machining setup should be as rigid as possible.

The cobalt-base superalloys, such as L-605 and J-1570, generally can be rated about the same as the nickel-base group for machining characteristics. However, the cobalt-base alloys are considered to be particularly abrasive; for this reason, special consideration should be given to tool design and preparation.

Tips for Machining

You will note a separate box (p. 99) which gives suggestions for machining space-age materials. Since these notes are likely to appear somewhat cryptic, the following amplification may help. The first two recommendations, which can be considered together, must be observed if one is to cope with the high shear strength of these alloys and the necessity for taking positive cuts at all times. Positive cuts are needed to prevent glazing or burnishing and work hardening of the surface.) A rigid setup also minimizes chattering, which causes work hardening, poor *(Continued on p. 145)*

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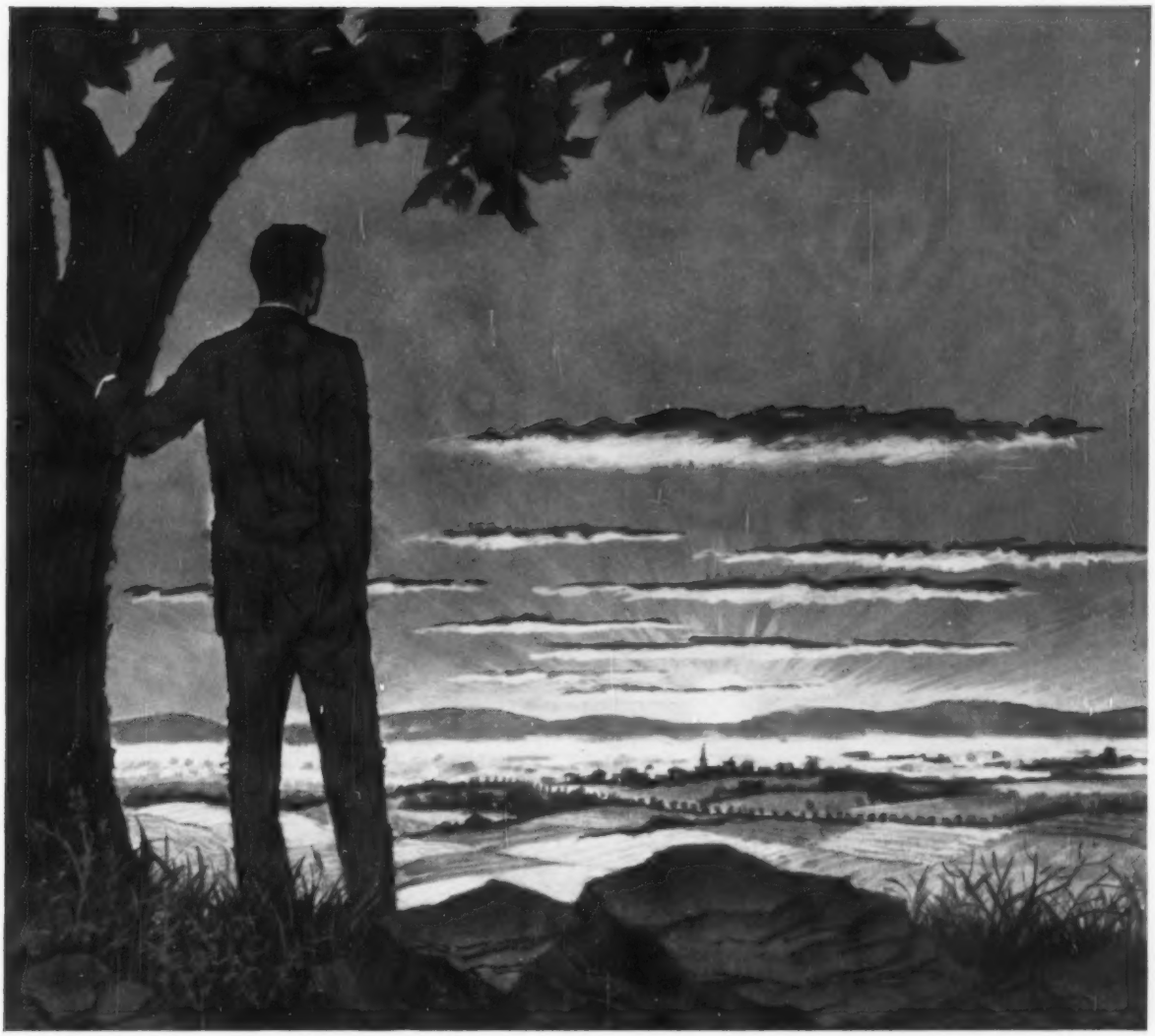
Machining A-286, Solution Treated and Aged to Brinell 321

Operation	Tool Material	Tool Geometry (*a*)	Tool Used for Tests	Depth of Cut	Width of Cut	Feed	Cutting Speed	Tool Life	Wear-Land (*b*)	Cutting Fluid
Turning	C-2 carbide	SR: 5°; SCEA: 15°; BR: 0°; ECEA: 15°; Relief 5°	½-in. square throw-away holder with mechanical chip breaker	0.100 in.	—	0.009 in./rev.	150 ft./min.	25 min.	0.016 in.	None
Turning	Stellite 98 M-2 cast alloy	SR: 15°; SCEA: 0°; BR: 0°; ECEA: 5°; Relief: 5°	⅝-in. square tool bit	0.060	—	0.009 in./rev.	50	60 min.	0.060	Soluble oil (20:1)
Face milling Down milling setup	C-2 carbide	AR: −4°; ECEA: 5°; RR: −11°; Cl: 10°; CA: 45°	5-in. diam., 5-tooth inserted-tooth face mill	0.100	2 in.	0.010 in./tooth	100	50 in./tooth	0.030 localized wear	None
Face milling	T-15 HSS	AR: 0°; ECEA: 5°; RR: 0°; Cl: 8°; CA: 30°	4-in. diam., single-tooth face mill	0.060	2	0.015 in./tooth	50	55 in./tooth	0.060	Soluble oil (20:1)
Side milling Down milling setup	C-2 carbide	AR: 10°; ECEA: 5°; RR: −5°; Cl: 8°; CA: 45°	7-in. diam., 6-tooth inserted-tooth face mill	0.100	1¾	0.005 in./tooth	120	47 in./tooth	0.016	None
Slot milling Down milling setup	C-2 carbide	AR: 10° binegative; RR: 0°; ECEA: 1°; CA: 45° × 0.030 in.; Cl: 8°	6-in. diam., 6-tooth brazed-tooth slotting cutter	0.250	1	0.005 in./tooth	150	30 in./tooth	0.016	None
End milling (*c*)	T-15 HSS	35° RH helix; CA: 45° × 0.060 in.; Per. Cl: 15°	¾-in. diam., 4-flute end mill	0.250	¾	0.002 in./tooth	40	100 in.	0.008 cutter breakdown	Highly sulphurized oil + light machine oil (1:1)
Drilling	T-15 HSS	2-flute, 118° standard point, 7° clearance	¼-in. diam. drill, 2½ in. long (*d*)	0.500 through hole	—	0.005 in./rev.	20	51 holes	0.016	Highly sulphurized oil + light machine oil (1:1)
Tapping	M-10 HSS	2-flute plug chip driver tap, 75% thread	5/16-18 NC plug tap	0.500 through hole	—	—	30	130+ holes	(*e*)	Highly chlorinated oil

(*a*) AR = axial rake; RR = radial rake; CA = corner angle; SR = side rake; BR = back rake; SCEA = side-cutting edge angle; ECEA = end-cutting edge angle; Cl = clearance.
(*b*) Wear on the peripheral flank of the cutter.
(*c*) For end mills ½ in. in diameter and over. Use shortest possible flute length for maximum rigidity.
(*d*) Use stub length drills for maximum rigidity.
(*e*) Test discontinued; tap still cutting.

Source: Metcut Research Associates, Inc.



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Circle 1229 on Page 48-B

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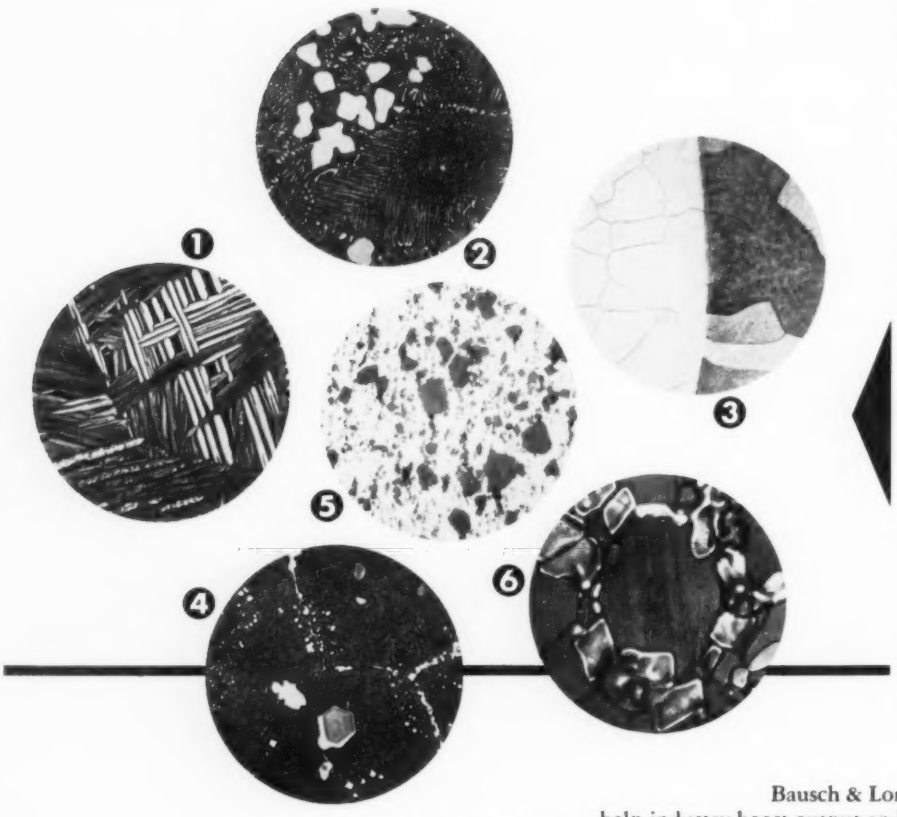

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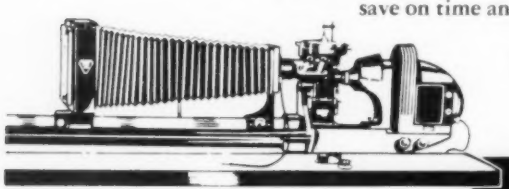

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Circle 1230 on Page 48-B

Producing for the New Technologies

Design and Manufacture of Reactor Vessels

*By D. K. DAVIES**

Difficulties arise from ignorance about radiation damage to steel and welds, from laminations and inhomogeneities in the plate, from lack of standardized test and inspection methods, and from quite limited experience with operating reactors. (T11, T26q)

TO THE UNINITIATED A REACTOR for a nuclear power plant looks a good deal like an ultra-husky autoclave, pressure vessel or boiler of peculiar shape. While the similarity is more apparent than real, we in the pressure and boiler industry (which has made the reactor vessels) have had to rely on old experience gained in building large drums and equipment long before the first chain reaction was harnessed, and long before accurate analytical methods were available for computing the stresses. A large proportion of our knowledge has come from field service, and adequate and safe design rules have been embodied in the American Society of Mechanical Engineers' Boiler and Pressure Vessel Code. In view of this history we know, then, that *environment* is often a determining factor in design.

This immediately brings forward a prime difference between design of a pressure vessel and a nuclear reactor – the fact that the latter is subject to radiation damage. Most environmental effects on vessels in the process or power industries begin with some sort of interaction between the surface of the vessel and the material in contact with it. This interaction sometimes leads to failure; but the failure usually appears first in the form of surface changes which are discoverable by visual or instrumental inspection so that remedial action can be taken before the defects endanger the integrity of the vessel. Radiation damage, on the other hand, is certainly not a surface effect. This presents us with two new circumstances: First, it can't be readily detected by surface inspection. Second, since its effects are not confined to the surface area, the chances are that failure, if it occurs, will not be of a progressive nature.

Design of Openings

The most serious effect of radiation damage from the standpoint of the pressure vessel designer is reduction in toughness and ductility of the steel. We have for years been designing pressure vessels with local areas of high stress.

*Chief Nuclear Component Specialist, Boiler Division, Babcock & Wilcox Co., Barberton, Ohio. This article is a shortened version of a talk Mr. Davies gave before the U. S. Atomic Energy Commission's Welding Forum.

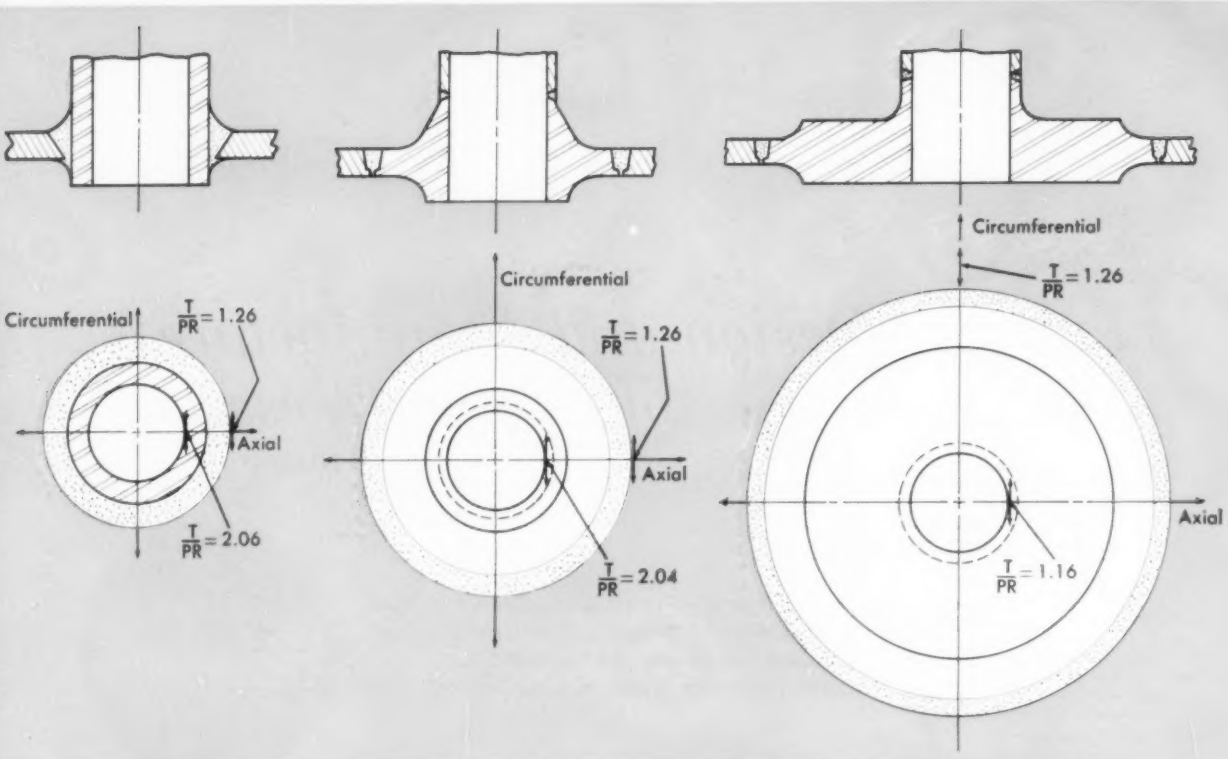


Fig. 1 – Nozzle Welded Into Drum Without Reinforcement. Stress at inner edge of opening is 2.06 times the circumferential stress in the wall some distance away

Fig. 2 – Nozzle Reinforced 15% More Heavily Than Suggested by Boiler Code. Stress at inner edge of opening is 2.04 times the circumferential stress in the wall

Fig. 3 – Unreinforced Hole in Much Thicker Wall (380% Reinforced). Stress at inner edge of opening is 1.16 times the circumferential stress in the wall

The inherent ductility of the steel has allowed us to do this with relative impunity. In all probability this is not true for nuclear reactor vessels – and we *must* therefore be able to predict with accuracy the strain levels in all locations susceptible to radiation damage. With all the mathematical work that has been done on shell theory, there still remain a number of problems for which we have no ready solution; few people realize the gap between the theoretician or experimenter and the designer who must apply his work. Even after he understands the theory and method of application, the designer must use it in such a way that it results in designs which can be built economically with available metals.

To be specific I will briefly indicate the situation existing at and around openings. The primary coolant nozzle certainly needs reinforcement, yet theory and experience prove that an over-reinforced nozzle may be more susceptible to failure than an opening without any reinforcement whatever. The accompanying sketches indicate stress concentration factors for three designs. Figures 1, 2 and 3 are derived from tests on a full-scale drum, checked by later theoretical analyses. Figure 2 portrays about the best obtainable. Reinforcement is 15% greater than suggested by the Code, and the stress at the edge of the opening is about double that in the pressure vessel shell. Figure 3 shows what is, in effect, an unreinforced hole in much thicker wall, which has a stress concentration factor of only 1.26, but it is costly and often cannot be used without interfering with heads, weld seams and closures.

The fact that the tangential stress in a cylindrical drum is twice the longitudinal stress is utilized in the elliptical nozzle shown in Fig. 4. By adding 20% more reinforcement to that required by the code, stress concentration factors as low as 1.19 may result. However, such

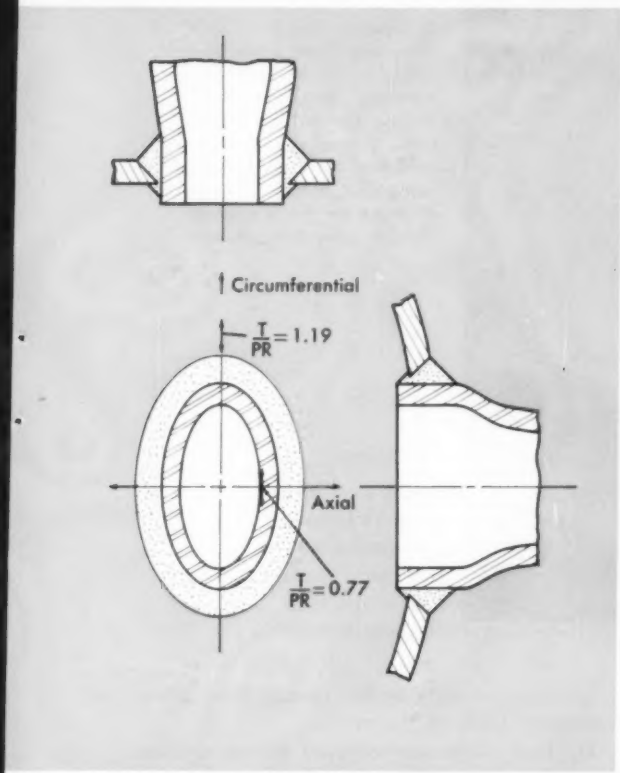


Fig. 4 – Stress Concentration Factor of 1.19 Achieved by Oval Nozzle, Reinforced 20% More Heavily Than Suggested by Boiler Code

a nozzle is very difficult and costly to make.

The stresses at openings should not exceed values which can be readily relieved by small amounts of plastic deformation during hydrostatic test and the first few operating cycles.

If the ductility is to be seriously damaged by high-intensity radiation, we believe that stress concentration factors should be less than 2.5. A simple precaution would be to place nozzles as far from the radiation source as possible – which should seldom be difficult. Abrupt discontinuities in thickness or contour, whether on interior or exterior surfaces, should either be avoided entirely or removed from regions of greatest neutron exposure. This includes support skirts, locating lugs, abrupt changes in shell thickness, and thermo-wells, instrument connections and other small unreinforced openings.

Even though the cylindrical shell carries smaller stresses than any other portion of the reactor vessel, it is not necessarily free from all discontinuities. Tool marks, gouges, dents or any such thing caused by improper handling can produce local areas of high stress, whose magnitude will depend on the well-known variables of notch depth, the shape of the root of the notch, and the number of such notches in a given area. Such markings on the internal surface are minimized if the vessel is clad, as will be indicated later.

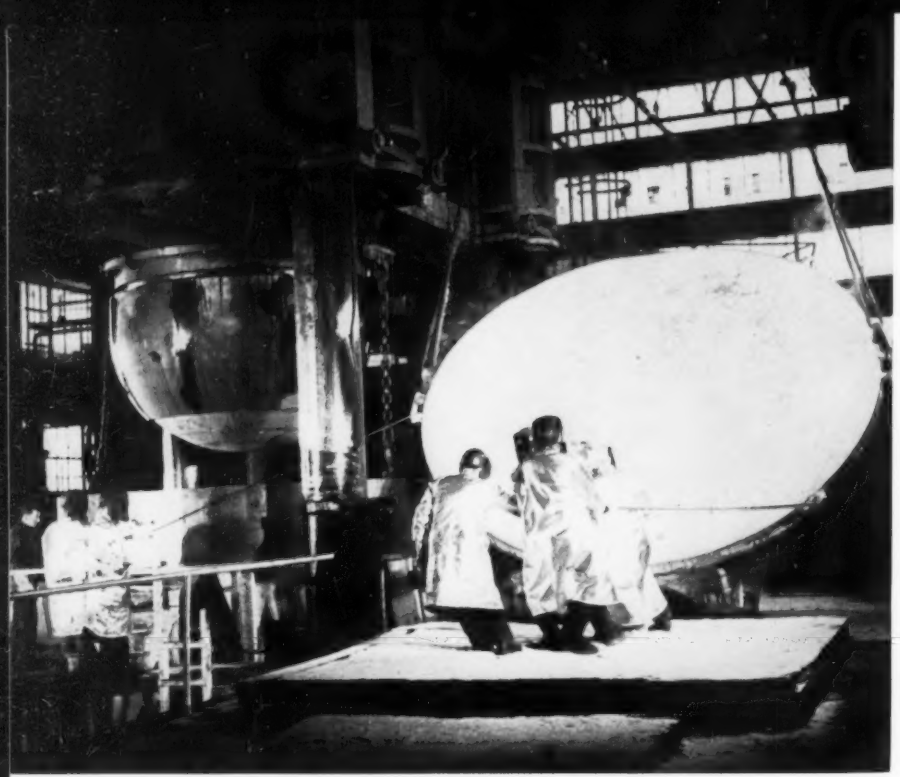
Material and Fabrication

So far, only design has been considered in examining the effect of irradiation damage on reactor pressure vessels. Several precautions must be used during manufacturing to minimize the effects of radiation damage. At the risk of stating the obvious, this subject will be briefly discussed because it is so important. It will also bring out some of the disadvantages of our present manufacturing techniques.

Starting with the raw material, there is a great deal which can be done to counteract the effects of service conditions on reactor vessels. The customary steel* has been melted and heat treated in such a way as to possess at least 15 to 30 ft-lb. impact resistance using a Charpy V-notch specimen at 10° F. This is usually obtained through the use of fast cooling rates during heat treatment. A receipt inspection, usually done at the fabricator's plant, consists of a complete ultrasonic examination, scrutiny of the mill tests and special reports, especially the toughening heat treatment to obtain the required Charpy values. There is no question but that the ultrasonic inspection is of great value and will continue to grow in importance because it allows us to discover and remove many of the interior imperfections not apparent to surface inspection.

During manufacturing, special care is taken in many operations. Some of them may, to the uninitiated, appear to have minor importance, but we in the boiler and pressure vessel industry

*Most reactor vessel shells are made from steel plate conforming to A.S.T.M. specification A 302, Grade B, "Magnesium-Molybdenum Steel Plates for Boilers and Other Pressure Vessels". Composition of plates over 2 in. thick is 0.25% max. C, 1.10 to 1.55 Mn, 0.45 to 0.60% Mo. Specified tensile properties are 80,000 to 100,000 psi. tensile strength, 50,000 psi. min. yield point, 17% elongation in 2 in. A bend test is also required wherein the standard specimen must bend at room temperature through 180° without cracking around a pin 3.5 times the thickness of the specimen.



A Glowing Red Steel Slab Weighing More Than 58,-000 Lb. Is Set for Die Forming at Babcock & Wilcox Co. in Barberton, Ohio. Forced into a hemispherical shape, it will become the bottom closure of a reactor for a nuclear electric generating station

know from ample experience that prior history of the constructional material has great influence on test results and especially on performance in service. For example:

1. The surfaces of the plates which are to be toward the inside of the vessel are either machined or ground smooth, prior to cladding.

2. Cladding, either by deposition of stainless weld metal or by spot welding a stainless sheet.

3. Hot forming at 2200° F. for plates to be formed into heads and at 2000° F. for those which are hot rolled into cylindrical shells.

4. Normalizing at 1750° F. – This operation may or may not be performed depending on the microstructure existing after hot forming.

5. Tempering at 1150° F.

6. Welding joints in thick steel shell and thin stainless cladding. Striking an electric arc anywhere on the surface is strictly prohibited. (In passing it might be mentioned that we do not have nearly as much information as we should have concerning the resistance of weld metal – joints – to radiation damage.)

7. The vessel is spray cooled from 1750° F. after welding.

8. Cold forming is sometimes required in small amounts to re-round cylindrical shells.

9. Stress-relieving at 1150° F. – This operation will be performed seven or eight times during various stages of manufacture depending on the exact fabrication sequence.

10. Exterior surfaces are usually Magnaflux inspected, 100% of the area.

11. Tool marks are removed wherever they occur.

12. Near the completion of the fabrication, after all heat treatments have been performed, samples are cut and subjected to additional Charpy impact tests to make sure that nothing has impaired the original toughness of the material.

13. Many vessels are spray quenched or subjected to other methods of rapid cooling to improve Charpy impact values which have fallen off during fabrication.

To a considerable extent the methods used for cladding take care of Item 1 in the above list. Depending on the type of cladding which is applied, the surface is either machined or prepared in some other way. In applying cladding by resistance welding, which Babcock & Wilcox Co. has used successfully for a number of years, the shell plate is ground on its interior surface, not so much because we are concerned with stress-raising discontinuities, but because a good surface is required for a good bond between the cladding and base material. Where weld-deposited cladding is used, it is customary to machine the inside so that, again, virtually all sharp discontinuities are removed (provided the finish is reasonably smooth). In addition, the surfaces are *(Continued on p. 148)*

Trends in Materials for Reactor Control Rods

*By J. B. GIACOBBE**

Hafnium still maintains its position as the most widely used control material, but the performance of rods made from a cadmium-indium-silver alloy and a stainless steel containing boron are being investigated in commercial reactors. Rare earths also look promising because of their high neutron absorption cross section. (T11j, 17-57; Hf, Ag-b, *Cd*, *In*, SS, EG-g)

BECAUSE OF THEIR ABILITY to absorb neutrons, control materials for nuclear reactors act as throttles which regulate the "speed" of the reaction. Today, most control materials are used in the form of rods that can be moved in or out of the core to maintain the desired level of reactivity.

For military cores, hafnium still remains the prima donna of control materials and virtually all of it is used for this purpose. The prime nuclear considerations are the non-burnout behavior of the material, adequate thermal absorption cross section and excellent resonances in the epi-thermal range. Metallurgical advantages of hafnium are its good corrosion resistance in hot water, adequate mechanical properties and workability. It can be welded satisfactorily, provided there is no excessive mechanical restraint during cooling.

As with other materials, hardness and rate of work hardening of hafnium are closely related to its impurity content and indirectly to melting technique. Both of these factors must be controlled within close limits to produce a material which can be welded and cold worked as required in control rod fabrication. Our experience to date indicates that strip having a hardness in excess of Rockwell A-55 presents fabrication difficulties.

For commercial reactors, we have fabricated control rods having two types of neutron absorbers: Type 304 stainless steel containing 2% boron and a 5 Cd, 15 In, 80 Ag alloy. Both control rods have a cruciform cross section and both absorbers are about ¼ in. thick. The boron-stainless section has a span of 15 in. and a length of 60 in. compared to 9 in. and 100 in., respectively, for the Cd-In-Ag section. Total length of each rod is about 17 ft.

The conventional method for fabricating control rods is to join three solid pieces by fusion welding. But because of the brittle nature of the resulting weld and the low notch sensitivity of the 2% boron alloy, the boron-stainless absorber was fabricated by spot welding, joining four 90° angles of the steel back to back but separated by a ⅛-in. thick spacer. Bending 1/16-in. plate around a radius of ⅜ in. is a difficult job because the alloy exhibits low ductility at room temperature. An elongation (in 2 in.) of only 5% is typical. Reasonable success was achieved by using steel back-up strips in the

*Director, Nuclear Products Div., Superior Tube Co., Norristown, Pa.

bending die and completing the 90° bend in a two-step operation. Zircaloy and boron-stainless cruciforms were joined with flush rivets because the two cannot be welded together.

Cd-In-Ag Alloy Extruded and Plated

The Cd-In-Ag alloy was extruded into a cruciform shape then machined to final dimensions. To protect the base alloy from corrosion in the reactor, it is plated with a thin coating of pure nickel. As with the stainless-zircaloy combination, there is no reliable method for joining the silver alloy to the zircaloy extension by welding or brazing. Instead, a stainless steel "interlock" was riveted to the silver alloy and the subassembly was in turn "locked" to the zircaloy extension. By careful attention to the riveting technique, an excellent joint is obtained.

During annealing, the rod must be supported in a special fixture to maintain close dimensional tolerances. This is necessary because the Cd-In-Ag alloy is quite soft and shows a relatively large creep rate at 1000° F., the annealing temperature.

Figure 1 shows a completed boron-stainless steel rod made for Allis Chalmers which should soon go into service at Elk River. The Cd-In-Ag rod made for Westinghouse is now in use at the Yankee Atomic Electric Plant. Performance of these two types of rods may well indicate the future trend in control materials.

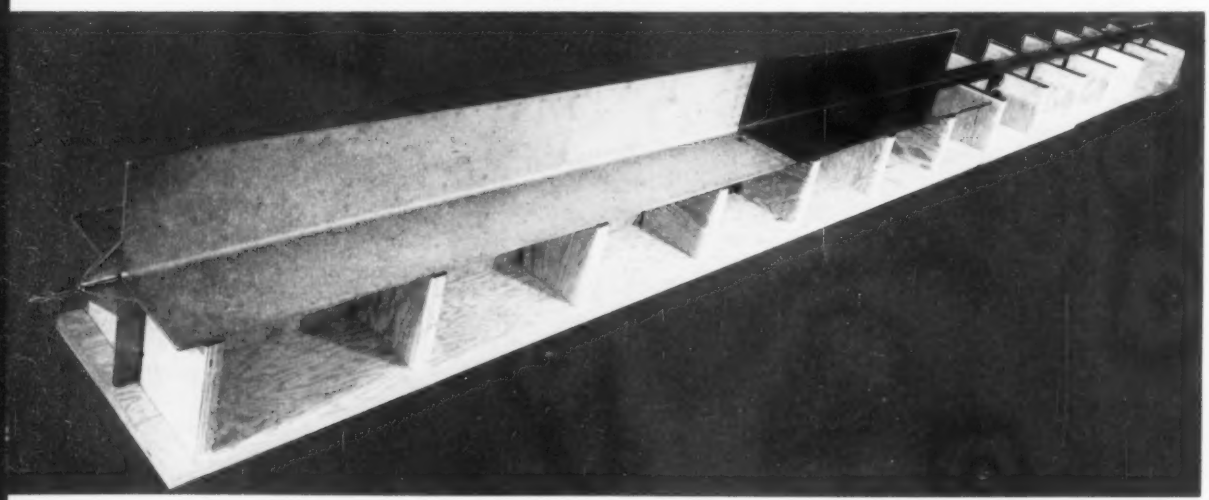
Rare Earths Being Studied

The possibility of using rare earth dispersions in a stainless steel matrix is now being investigated for commercial control rods. As shown below, the rare earths have extremely high absorption cross sections but what is equally important, these materials suffer relatively little radiation damage. Reliable performance in service can, therefore, be expected over longer periods of time.

Material	Isotope	Cross Section
Samarium (Sm)	149	66,000 barns
Sm_2O_3	151	12,000
Gadolinium (Gd)	155	70,000
Gd_2O_3	157	160,000
Dysprosium (Dy)	161	730
Dy_2O_3	164	3,000
Europium (Eu)	151	9,000
Eu_2O_3	155	13,000
	153	400
Hafnium (Hf)	174	115
Cadmium (Cd)	106	2,550
Boron (B)	10	755

Although the rare earths are expensive, production of these materials has developed rapidly during the past five years, accompanied by a significant decrease in price. Furthermore, because of the extremely high absorption cross section of the rare earths, only small amounts are needed. This should provide impetus for development of this type of control rod.

Fig. 1 — Control Rod for Nuclear Reactor Is Fabricated From Type 304 Stainless Steel Containing 2% Boron Formed as a Cruciform and Riveted to a Zircaloy Extension. Performance of this and other new types of rods which represent a departure from those made of hafnium will influence future trends in the choice of control materials



Materials and Fabrication Methods for the Bomarc

*By R. H. NELSON**

To build the Bomarc, Boeing engineers tap a broad range of experience in metals selection and fabrication. Backbone of the missile is a series of tanks made from stainless steel and aluminum alloys. Titanium spars support the control surfaces and the tail assembly is covered with a magnesium alloy skin. Described here are some of the fabricating methods that are used. (T24e; SS, Al, Ti, Mg)

THE AIR FORCE'S IM-99 BOMARC, built by Boeing Airplane Co., is a long-range, supersonic, surface-to-air missile designed to seek, intercept and destroy enemy aircraft and certain types of other missiles. Guided to the target area by ground control, its radar then takes over and directs the missile to the kill. The "A" model Bomarc, having a range of more than 200 miles, is launched by a liquid-fueled rocket and powered in flight by two ramjet engines. The newer "B" model uses a solid-propellant "boost" rocket. Improved ramjet and greater fuel-carrying capacity give it a range of more than 400 miles.

As can be seen in Fig. 1, an exploded view of the "A" model Bomarc, a series of three pressure tanks, each 35 in. in diameter, make up the major portion of the missile's 47-ft. body. Walls of the tanks form the outer surface and structural backbone of the missile. In front of them is a fiberglas radome and a connecting aft nose body section; behind them is the boost rocket engine and the tail assembly. A fairing, which runs along the top of the missile,

*Bomarc Manufacturing Manager, Aero-Space Div., Boeing Airplane Co., Seattle, Wash. Acknowledgement is made to Boeing research engineers Richard Crial, John Crandall, William Gorrell and Lowell Jackson and to technical writer Howard Dillman for their help with this article.

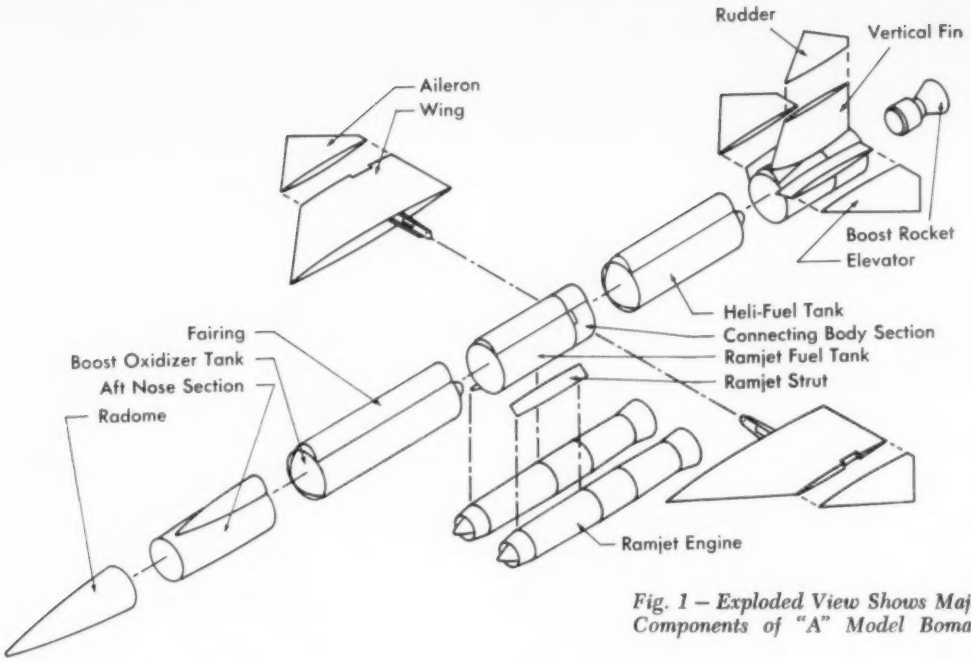


Fig. 1 – Exploded View Shows Major Components of "A" Model Bomarc

houses plumbing and electrical wiring. Struts for the ramjet engines fasten to the ramjet fuel tank and the wing spars are attached inside a connecting body section between the ramjet fuel and the heli-fuel tanks. The latter – really two tanks welded together – is made up of a cylindrical vessel for the liquid rocket fuel and a pressure vessel for helium. Compressed helium supplies pressure to the rocket fuel tank, the boost oxidizer tank, and the ramjet fuel tank to expel the liquids in these tanks through connecting plumbing to the rocket and ramjet engines.

Appearance of the "B" model Bomarc is similar to that of the "A" model. However, since the "B" model uses solid rocket fuel, it does not need the boost oxidizer and heli-fuel tanks. These are replaced by a solid-propellant motor case in the aft end of the missile. Elimination of these heavy tanks saves both weight and space and permits installation of a larger ramjet fuel tank. Much of the connecting plumbing is also eliminated. This leaves space under the fairing on top of the missile for three 8-ft. air bottles, each 5-in. in diameter. Two of these bottles supply operating pressure for the ramjet fuel tank; the third pressurizes the nose section to help cool electronic equipment.

Wide Range of Alloys

Because of their light weight, aluminum alloys find extensive application in the Bomarc. The fuel tank for the ramjets on the "A" model is fabricated from 6061-T 6 aluminum which has a minimum strength of 42,000 psi. To reduce weight in the "B" model, its ramjet fuel tank is made of 2219 aluminum – a newcomer in the aluminum-copper series which has a minimum strength of 58,000 psi in the T 6 condition. Most of the body and control-surface framing members, as well as the skin in certain areas of the body and wings, are 2024 aluminum.

Magnesium also has an important role in the Bomarc. The fairing atop the missile, certain skin areas on the body and wings and all the skin area of the tail assembly are thoriated magnesium (HK-31), a lightweight material that retains a moderately high strength level at elevated temperatures.

Until recently, spars for the control surfaces were machined from 4340 steel forgings having an ultimate tensile strength of 160,000 psi. Fin and elevator spars are now being made of 7 Al, 4 Mo titanium alloy. This alloy has high tensile strength (180,000 psi.), excellent fatigue characteristics, and it results in a worthwhile weight saving.

Corrosion resistant 17-7 PH stainless steel heat treated to 165,000 psi. forms the boost oxidizer tank and the heli-fuel tank in the "A" model Bomarc. Chemical stability of the solid rocket fuel in the "B" model eliminates the need for a corrosion resistant material in the rocket motor case. However, the manner in which

the solid rocket fuel burns demands an alloy of high strength-to-weight ratio. Low-alloy, air hardening 4330 M steel was selected for this application because it can be heat treated to the required strength level of 170,000 to 190,000 psi. It is easily formed and machined, and it can be welded without pre and postweld heating control.

The three 8-ft. air bottles, mounted under the fairing on the "B" model Bomarc, have been fabricated from several materials – each change resulting in a weight saving. Originally they were made by spinning closed ends on lengths of seamless 4130 steel tubing. Next, the ends of 7075 aluminum tubes were swaged shut to form these bottles. Now resin-impregnated fiberglas thread is wound about a salt "melt-out" mandrel to build up the required wall thickness. When cured, it forms a strong, light-weight bottle.

Resin-impregnated fiberglas is also used for the radome which must be a light, strong material through which radar waves may pass with little distortion or energy loss. The 8½-ft. Bomarc radome is built up by winding layers of the impregnated fiberglas thread longitudinally and circumferentially about a mandrel. At supersonic speeds, the radome's long streamlined shape protects it from rain erosion, except for a very small area on the tip of the nose. This area is protected by a metal tip too small to interfere with radar performance.

Control Surfaces and Body Sections

Bomarc control surfaces are constructed much like similar components for conventional aircraft, being made up of a framework of ribs and spars to which a metal skin is riveted. Control surfaces are secured to the missile by spars bolted to heavy frames in the body sections. Body sections, other than tanks, are also fabricated by conventional methods and consist of a metal skin riveted to a suitable framework. These sections house the missile's power supply, electronic control and guidance equipment, hydraulic unit and rocket engine.

Machining Titanium Spars

The recent change from steel to 7 Al, 4 Mo titanium for the fin and elevator spars necessitated new machining processes and tooling. Tests have established that a better finish and longer tool life is obtained if the titanium alloy is machined in the fully aged condition. This material, however, resists cutting and tends to spring away from the tool. Nesting fixtures which provide complete and rigid backup to the workpiece during machining overcome the problem and assure an accurate part with a good finish.

Some distortion due to stresses induced or released by machining was anticipated. In most instances, however, distortion, though measurable is very minor. The part is first rough-machined all over and then finished – care being taken to balance all cuts so that distortion is held to a minimum.

The completed spar is a tapered, modified H-section. Its inside surface is milled on a numerically controlled Kearney-Trecker mill. For this operation, high speed toolsteel cutters with a high helix angle perform best because the tooth pressure is more evenly distributed during the complete revolution of the tool. Outside surfaces of the spar are machined on a Rockford tracer-controlled planer. The holding fixture of the planer is built to accommodate three spars simultaneously while a master templet controls the path of the cutting tools. Heat generated in machining the 7 Al, 4 Mo titanium spar dissipates from the cutting tool very slowly. Of the coolants tested, a mist coolant produced the best results. Recommended feeds and speeds developed for machining the 7 Al, 4 Mo titanium spars are given in Table I.

Attach slots are milled in the spar on a conventional horizontal mill. Holes in the web of the spar (to decrease weight) are made on a drill press, using a standard high speed steel counterbore which has been modified to a trepan tool.

Holes for attaching the magnesium skin to the titanium spar are drilled through both the skin and the spar at the same time without coolant. High-speed cobalt drills having a 135°-90° split point and a 3°-5° positive rake angle produce these skin-spar attachment holes with minimum burring and close control of size.

Table I – Machining Conditions for 7 Al, 4 Mo Titanium Alloy Spars

	Speed	Feed
Milling	40 to 60 sfm.*	0.004 to 0.006 in. per tooth
Drilling	20 to 30	0.002 to 0.004 in. per rev.
Trepanning	20 to 30	0.003 to 0.005 in. per rev.
Planing	20 to 30	0.010 in. per stroke

*Surface ft. per min.

Fig. 2 – Nut Plates Are Riveted to Forward Head Assembly of "B" Model Bomarc Ramjet Fuel Tank. This mechanical joint permits installation and inspection of a rubber fuel-displacing bladder. Aft section of the tank, to which the head will be bolted, is at the operator's right

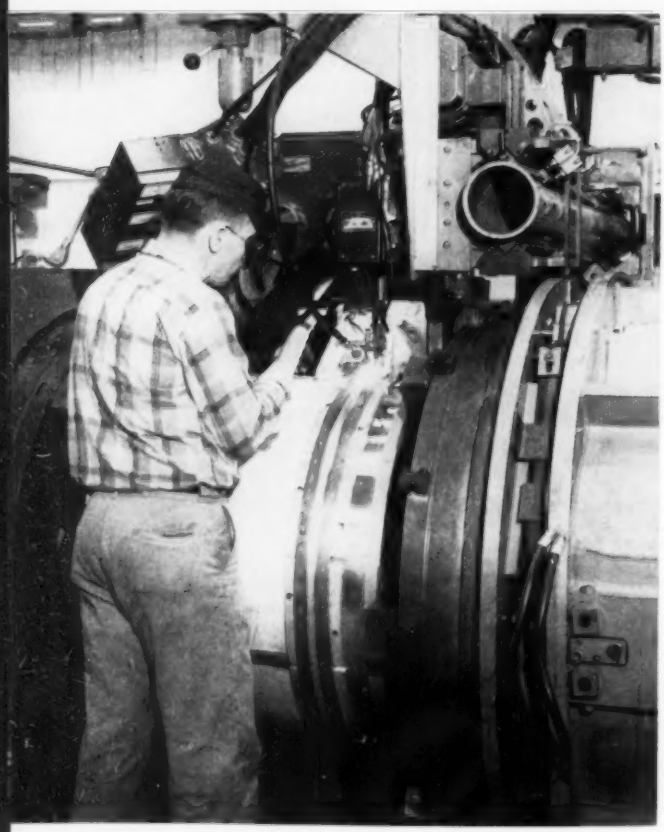


Fig. 3 – During Welding of Components of Aluminum (2219 Alloy) Fuel Tank, an Internal Mandrel Expands Parts Tightly Against the External Girth Rings on Both Sides of the Joint. Here a forged ring and a section of the tank are being joined

Fabricating Aluminum Tanks

Rolled and welded shell sections, forged and machined rings, and draw-formed heads make up the aluminum ramjet fuel tanks. In fabricating these parts, allowances must be made for dimensional changes which will result from welding and heat treatment. This requires careful trimming and machining to assure proper spacing between structural attachments and that the finished tank has the correct volume and meets the stringent aerodynamic demands for supersonic flight.

Shell sections for the ramjet fuel tanks are rolled from aluminum alloy plate to a diameter which allows for weld shrinkage. To eliminate as much weight as possible, the interior surface of the rolled shell section is chemically milled to reduce the wall thickness in all areas except along the edges which are to be welded or in the special stiffening belts. The longitudinal joint in the rolled shell section is welded in a

Fig. 4 – Ramjet Fuel Tank Section Ready for Heat Treatment. Internal fixture prevents buckling and distortion during solution heat treatment and quenching

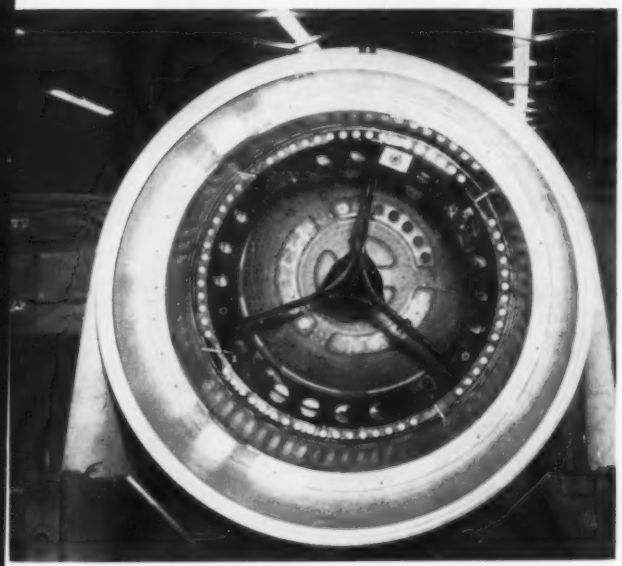


Fig. 5 – Components of Pressure Vessel for Helium Are Machined From Forged 17-7 PH Stainless Steel. Tank consists of two heads welded to a center shell section. Completed tanks appear in background

special stake fixture. Water pressure actuates rows of hold-down fingers which press the abutting edges of the rolled shell firmly and uniformly against a chromium-plated copper back-up bar. Mechanized welding equipment, supported on a horizontal beam over the holding fixture, travels at a preset rate along the joint, welding the edges together. The shell section is then trimmed to the proper length and, if necessary, sized diametrically on a Grotnes sizing machine.

Forged aluminum rings serve various purposes in the ramjet fuel tank. In the "A" model, a heavy ring forged in a closed die supports the engine struts. In the "B" model, the ring is roll forged and machined. A rubber fuel-displacement bladder is attached to another ring. Attach rings with nut plate assemblies form pressure-tight mechanical joints between the ramjet fuel tank and boost oxidizer tank in the "A" model missile, and between the forward and aft sections of the "B" model ramjet fuel tank (Fig. 2). Roll forged and machined Y-section rings welded to skirt sections and draw-formed domed heads are used in the tank head assemblies.

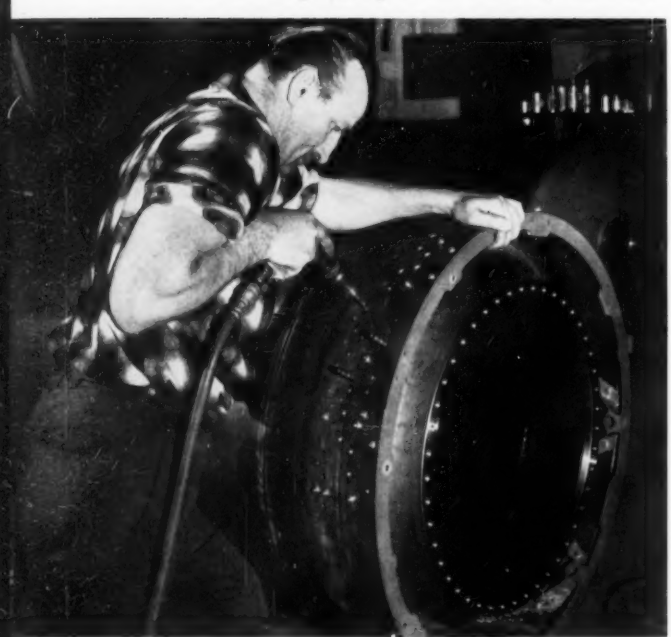
Fitting bosses, machined from aluminum bar stock and forged block, are mounted in holes bored in the tank shell and aft head. In the "B" model, only the large outlet fitting boss in the aft head is welded in place. The remaining smaller fitting bosses are bonded in place after the tank has been solution heat treated, utilizing the temperature of the subsequent aging cycle to cure the bond.

Head subassemblies, rings and shell sections are joined by girth welds made with the parts positioned on an internal expanding mandrel. This mandrel forces chromium-plated copper back-up shoes outward expanding the tank parts tightly against two external girth rings of a fixed diameter, thus assuring good fitup. The positioner, with the joining parts held firmly in place, rotates beneath the welding arc to make the girth weld as shown in Fig. 3. All welds on the ramjet fuel tanks are made with tungsten-arc inert-gas equipment, using automatic voltage control, direct current, straight polarity and helium shielding; two-pass, square butt-welded joints are used throughout, with most of the filler wire being added in the first pass. The second pass reduces porosity and brings the top weld bead to the desired contour.

Of the heat-treatable aluminum alloys, 2219 is apparently the most readily welded. Naturally there have been problems; probably pre-weld cleaning has been one of the worst. In the as-welded condition, welds in 2219 are very

Fig. 6 – Grinder Smooths Girth Weld in Heli-Fuel Tank to Improve Aerodynamic Flow. View shows forward end of helium tank (foreground) and aft end of boost fuel tank (background)

Fig. 7 – Drilling Holes for Fastening Body Joining Ring to Aft End of the Solid-Propellant Motor Case. Rocket blast tube will be attached to the large fitting in the center of the head



susceptible to intergranular attack. Therefore, once a part has been welded, it must not be cleaned further in alkaline cleaners or acids. Welded parts or subassemblies are vapor degreased, manually wire-brushed using powered, rotary wire brushes, rubbed with stainless steel wool and wiped with clean gauze just before positioning. Care is exercised in keeping the joint area from contacting anything other than the weld back-up before welding. When parts are accidentally contacted, they are wiped with clean gauze saturated with methyl ethyl ketone.

Another problem area is in making stops on girth and fitting welds. Minute crater cracking will occur unless very "cold" stops are made. Such cracks do not show on X-ray film after welding, but they are frequently revealed when the part is X-rayed after heat treatment.

Welds are inspected visually and by dye penetrants and, if acceptable, X-rayed. Requirements which the ramjet fuel tank welds must meet to pass X-ray inspection are among the highest in the missile industry for 6061 and 2219 aluminum alloy welds.

The welded ramjet fuel tank sections are heat treated in a vertical furnace. A special fixture (Fig. 4) fits inside the tank to prevent shrinkage, slumping and distortion during solution heat treating and the subsequent quench in water at 150° F.

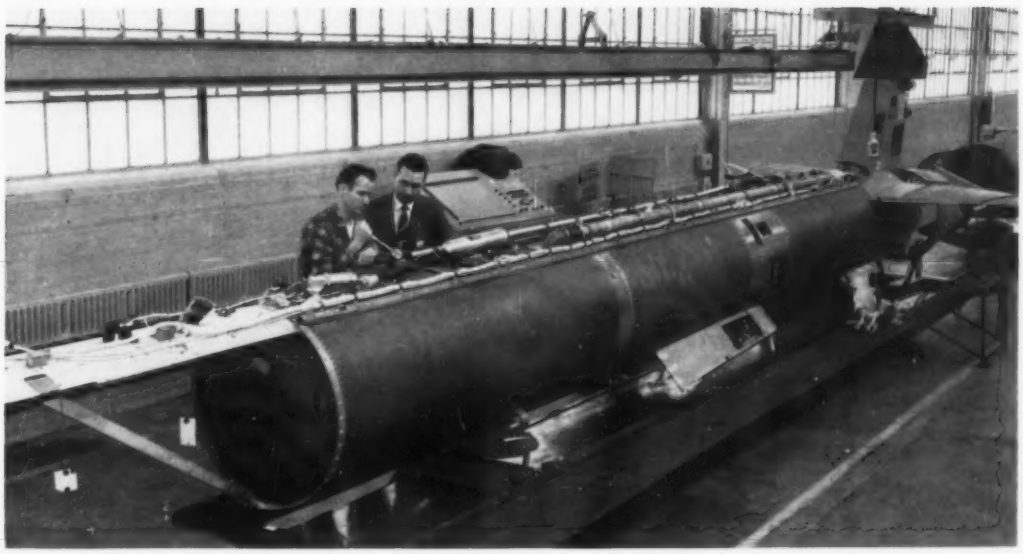


Fig. 8 – Tanks Make up Most of the Body of the "A" Model Bomarc. From left to right are the boost oxidizer tank, ramjet fuel tank, connecting body section, heli-fuel tank and tail assembly and aft body section

Stainless Steel Tanks

A high-pressure helium vessel comprises the forward end of the 17-7 PH heli-fuel tank in the "A" model Bomarc. Major components of the helium tank, pictured in Fig. 5, are two hemispherical heads and a center section. These components are machined from heavy forgings to a finished wall thickness of about 5/8 in. to withstand an operating pressure of 4300 psi. The thick center section also serves as an auxiliary anchoring point for the wing.

A heavy boss, integrally forged and machined as part of the forward head, provides an outlet for the helium tank. This outlet fitting is machined to extremely close tolerances after all welding is completed. Both the forward and aft heads have a Y-section machined in their circumference to permit attachment of cylindrical skirt sections.

Heavy walls of the helium tank components are used advantageously *(Continued on p. 142)*

Fig. 9 – Bomarc Missile, Near Completion, Rests in Test Fixture. All components are thoroughly tested before the missile is turned over to the Air Force

Refractory Coatings for High-Temperature Protection

*By JOHN V. LONG**

Base metals can be made more heat resistant by converting them to "composites" with techniques that modify the surface or apply a refractory coat. Surface materials discussed include glassy and matte ceramics, cermets, metallic and diffused metallic coatings. (L27, L15, L23, 2-62)

MANY HIGH-TEMPERATURE PROBLEMS in missiles and satellites are being solved with refractory coatings. The engineer who recognizes the causes of deterioration and failure in metals will find that a study of the many types of refractory protective coatings may solve his down-to-earth materials problems involving high temperatures. For instance, a ceramic coating will protect a copper or beryllium nose cone from temperatures as high as 6500° F. The same principle – that of producing a thermal drop – is being evaluated for the protection of aluminum piston heads in internal combustion engines employing similar types of ceramic coatings (Fig. 1).

A comparatively inexpensive, nonstrategic

*Director of Research, Solar Aircraft Co., San Diego, Calif.

Aluminum-Coated René 41 Turbine Nozzle Vanes for J-93 Engine, Ready for Diffusion Treatment

alloy may have suitable strength properties but its use is precluded by poor oxidation resistance at service temperature. By using protective coatings, the base material is protected from oxidation, allowing it to be used to the limit of its structural capability. Thus, less costly alloys will often perform as well as uncoated corrosion and heat resistant steels and alloys, and the latter (when coated) will have a longer service life at even higher temperatures.

Why are there so many different types of coatings? The primary reason is that there are many protective coating requirements and no single coating can provide all the properties desired. These include:

- **Corrosion and oxidation resistance** – Condensation products at room temperature and combustion products in the higher ranges severely attack metal surfaces, particularly mild steels. A protective coating prevents corrosion of the base metal and resists oxidation.
- **Erosion resistance** – Metal surfaces may be severely damaged by impingement of hot gases, flames, and small particles of combustion products moving at rapid rates. Refractory coatings will minimize this damage by providing a buffer between the combustion area and the metal confining the process.
- **Thermal insulation** – Even though a metal

Fig. 1 – These Plasma Arc Sprayed Aluminum Piston Heads Show the Results of an Impact Test to Determine Coating Adherence

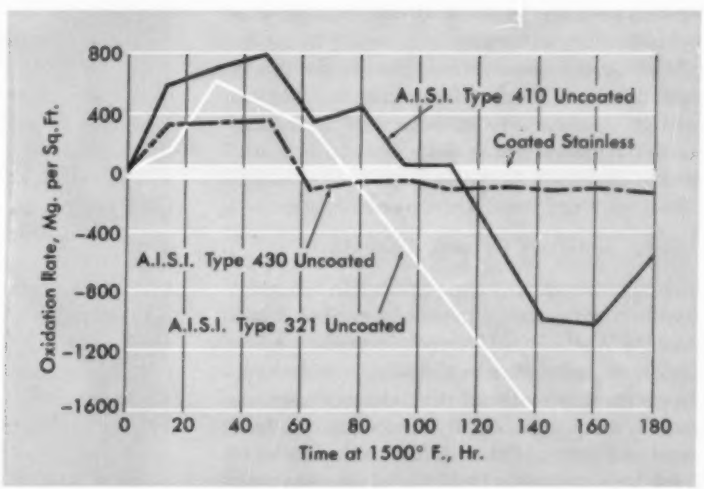


Fig. 2 – Oxidation Rates at 1500° F. on Uncoated and Coated Type 410, 430 and 321 Stainless Steel. The coating is a typical glassy or vitreous type

Fig. 3 – High-Pressure Bellows and Duct System Coated to Protect Low-Alloy Steel From Oxidation and Corrosion

may not be capable of withstanding high temperatures for the brief period during which a rocket motor is in operation, an insulating coating will keep the base metal cool enough so it will not soften and melt.

• **Electrical insulation** – Increased power capabilities and thermal flight have brought the need to operate continuously at higher than normal temperatures. Since standard insulations break down at relatively low temperatures, refractory types have found increasing use.

Vitreous or Glassy Ceramic Coatings

These decorative and protective coatings have been used for quite some time, but it was not until World War II that the porcelain enameler's techniques were modified to provide high-temperature protection. Vitreous coatings are smooth, nonporous, tightly bonded to the base metal and resistant to temperatures up to 1800° F. for long periods. This type of ceramic coating can be used to protect such metallic structures as exhaust stacks and flame dampeners.

Operating temperatures have gone upward and greater protection is needed. Improvements have been made by adding refractory materials such as alumina, zirconia, titania, and ceria to the coatings. As greater amounts of these compounds were added, both the appearance and character of the coatings changed until a new member of the coating family – the "matte" finish – was created. Coatings of this kind are protective to 2300° F.

Figure 2 illustrates the protection which can be expected from the vitreous or glassy-type coating developed to prevent oxidation, carburization and sulphurization of chromium-containing steels at elevated temperature. This coating protects exhaust manifolds, turbohoods and combustion chamber liners where extended life or a reduction in critical alloying materials is required. In another application, an inner liner on an afterburner was coated with ceramic, allowing stainless to replace a more expensive alloy. Equal service life was obtained.

Coating for Low-Alloy Steel

Another low-fired, vitreous coating was developed to prevent oxidation, decarburization, and corrosion damage to low-alloy steels. The coating can also be fired on copper-base alloys and stainless steel, and has found additional use as an electrical insulator. An interesting recent application is shown in Fig. 3. Here a high-pressure bellows and duct system made of low-alloy steel has been coated to prevent oxidation and corrosion at 850° F. The firing temperature was only 1000° F.

Glassy coatings are beneficial in other ways – for example, they improve the fatigue life of thin sheet. A ceramic-coated bellows showed a tenfold increase in fatigue life for a given stress level. Some vitreous coatings also provide good electrical insulation. Reactor tubes have been coated to insulate against potential differences as high as 30,000 v.

Semivitreous or matte coatings are obtained by making additions to glassy coatings. A typical example is a titania addition to protect superalloys at temperatures above the useful range of a glassy coating. Such additions extend protection 300° to service temperatures of 2150° F. This coating is specified for turbojet combustion liners, transition liners, afterburner flame-gutters and shrouds.

Metallic Coatings Increase Protection

Parallel with the development of glass coatings came another coating program designed to improve the surface resistance of base metals with a thin layer of a second metal more resistant to oxidation and corrosion. Chromium, nickel, titanium, aluminum and combinations of these have been successfully used to provide a thin, closely bonded protective layer. Chromium can be applied by chromizing, nickel by plating, titanium by plating from fused salts, and aluminum by a variety of methods.

When the metallic coating is diffused into the surface of the base metal, the surface becomes a new alloy. For example, when aluminum is diffused into the base metal, an aluminum-rich surface layer is obtained which has increased oxidation and corrosion resistance (see photo on p. 114). At Solar, metallic coating processes were developed to resist oxidation, carburization, sulphurization, attack by hydrogen and hydrogen sulphide gases, erosion and galling on alloys requiring a firing temperature between 1200 and 1300° F. A typical coating – applied to A.I.S.I. 1010, Timken 17-22 A, or cast iron – consists of an aluminum layer, metallurgically bonded to the base metal. A modification of the process was developed to protect titanium and titanium alloys from absorption of oxygen, nitrogen, and carbon at temperatures up to 1500° F., and to prevent galling of titanium during forming operations.

Fig. 4 – Ceramic Method of Aluminizing. A pot burner for a small gas turbine is being dipped into a slurry of ceramic and aluminum prior to drying and firing

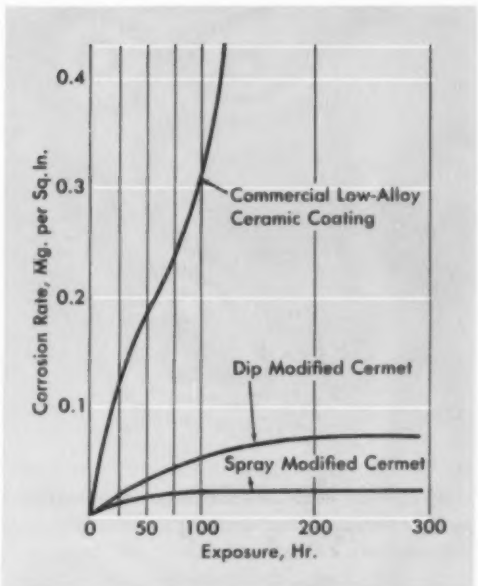


Fig. 5 – Resistance of Some Coatings to Oxidation at 1100° F. The base metal is A.I.S.I. 1010 steel

Diffused metal coatings provide refractory protection at temperatures far in excess of those which limit the usefulness of vitreous and matte ceramics and nondiffused metallic coatings. Diffused aluminum coatings are beneficial on a variety of base metals from low-alloy steels through superalloys; operating temperatures of the base metals may be safely increased from 300 to 500° F., and, in addition, service life will usually be extended.

The ceramic method of aluminizing is a new approach to metalizing. In Fig. 4 a pot burner for a small gas turbine has been dipped into a slurry of ceramic and aluminum. After drying, the coated part is fired to diffuse the aluminum into the base metal. The following table dem-

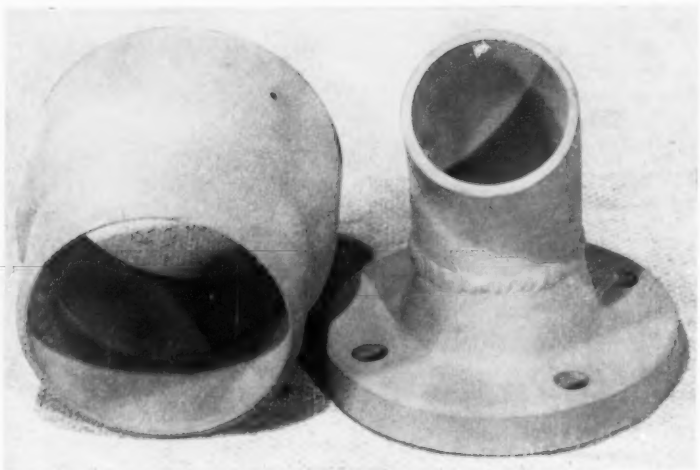


Fig. 6 – Aluminum-Ceramic Coating Applied to Heavy Pipe Sections. Low-alloy steels are protected up to 1100° F. Note good coverage on welds and sharp corners

onstrates the oxidation resistance of this coating on some alloys subjected to 500-hr., high-temperature oxidation tests:

Alloy and Test Temperature	Weight Change, Mg. per Sq.In.
17-22 A	
Uncoated (1200° F.)	−147
Coated	+ 4
A.I.S.I. 321	
Uncoated (1850° F.)	−1432
Coated	+ 20
Inconel	
Uncoated (1850° F.)	+ 5
Coated	+ 4
Uncoated (2100° F.)	−358
Coated	− 56
L-605	
Uncoated (1850° F.)	− 9
Coated	− 15
Uncoated (2100° F.)	−1330
Coated	− 121

In a specific corrosive medium (vanadium pentoxide, sodium oxide, and carbon), an aluminized sample of Type 321 stainless showed only stains after 30 min. at 1900° F.; the uncoated sample was completely severed.

Because diffused aluminum coatings are usually harder and more brittle than the base alloy, designers are concerned about possible deterioration of fatigue properties. In testing standard sheet specimens, it was found that fatigue strength of Type 347 stainless is actually increased (from 34,000 to 46,000 psi.) by application of a diffused aluminum coating.

Cermets Offer Excellent Potential

The coatings thus far discussed are composed of either ceramic materials or metals. Cermets, as the name implies, are materials in which ceramic and metallic components are combined to produce a coating which capitalizes on the best characteristics of each and offsets the disadvantages inherent in each. For example, ceramic coatings are brittle. By adding powdered metal to the glass, some degree of ductility is achieved. However, glass is far more oxidation resistant and provides protection for the base metal and the metal in the coating.

Cermet coatings, especially those which are designed to provide protection for carbon and low-alloy steels, are proving quite useful. We have developed aluminum-ceramic combinations, called "Alcermet" coatings, which have excellent workability; they can be applied to almost all low-alloy ferrous materials with beneficial results. Their use has eliminated many of the usual process difficulties such as fishscaling, pinholing, and poor bond which are encountered when formulations not specifically designed for coating are used.

Figure 5 shows the excellent oxidation resistance of cermet coating on A.I.S.I. 1010 steel, compared to a standard commercial ceramic coating. Thick or thin components can be fired without burn-through or other defects. The parts shown in Fig. 6 vary in thickness from ¼ to 1 in. and they contain welds, sharp edges, and other areas difficult to coat. The coating is easily applied to such items and can be fired for as little as 5 min. or for as long as 1 hr., with equally satisfactory results. This is important in fabrications made of thick and very thin components where the thin sections tend to "over-fire".

While defense applications of aluminum-ceramic coatings have been limited, there has been an immediate acceptance by commercial users. In Fig. 7, the coating is being applied to forced-air heating units. Other uses for aluminum-ceramic coatings include water heaters, oil storage tanks, automobile exhaust pipes and mufflers, and incinerators.

Flame Spraying

The successful application of coatings to metals and alloys can be attributed in large part to the work of the porcelain enameler. Briefly, he grinds a low-melting glass in a liquid vehicle, sprays or dips the metal part into the mixture, then fires the part in a furnace (at a temperature well below the softening point of the metal) to fuse the glass into a continuous layer. Improvements and modifications have extended this art to the high-temperature protective coating field. In many instances, however, extreme high-temperature resistance or thermal insulation is required and the coating materials that are used cannot be fused and will not bond at a firing temperature below the melting point of the base metal. For example, what do you do when you want to coat steel with aluminum oxide or zirconium oxide, both of which melt above 3500° F.?

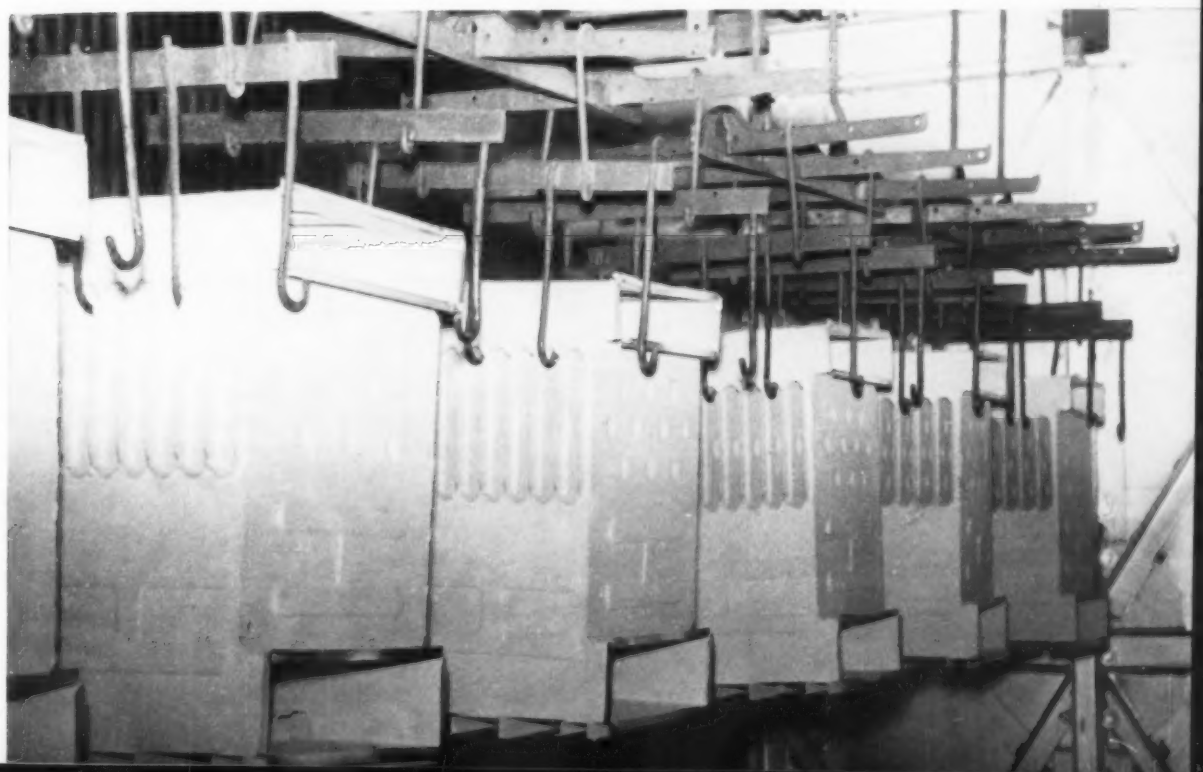
The answer lies in flame spraying, which is rapidly advancing to meet the requirements of high-temperature thermal insulation and erosion resistance. In this process the coating material is forced at high pressure through a spray gun; the high temperature produced in the combustion chamber readily melts the refractory material, which is projected to the surface of the part to be coated. Upon contact, the molten droplets flatten and bond to the base and to each other, and the coating gradually builds up to the desired thickness. The part itself can be cooled, or maintained at a temperature at which desired base-metal properties are retained.

Three general types of flame-spraying equipment have been developed; feed material can be either liquid, powder, or rod. Many spray guns are available commercially and all appear to be quite effective. An automatic setup can be employed for powder flame spraying symmetrical parts such as rocket nozzles. Hand spray guns are useful for flame spraying cermets, such as nickel-magnesium oxide and other combinations.

More Sophisticated Applications

A great deal of technical knowledge is required, however, before successful coating can be achieved. Once the basic coating technology is assimilated, it is possible to approach com-

Fig. 7 — Forced Air Heaters After Coating with Aluminum-Ceramic Mixture at Payne Div. of Carrier Corp.



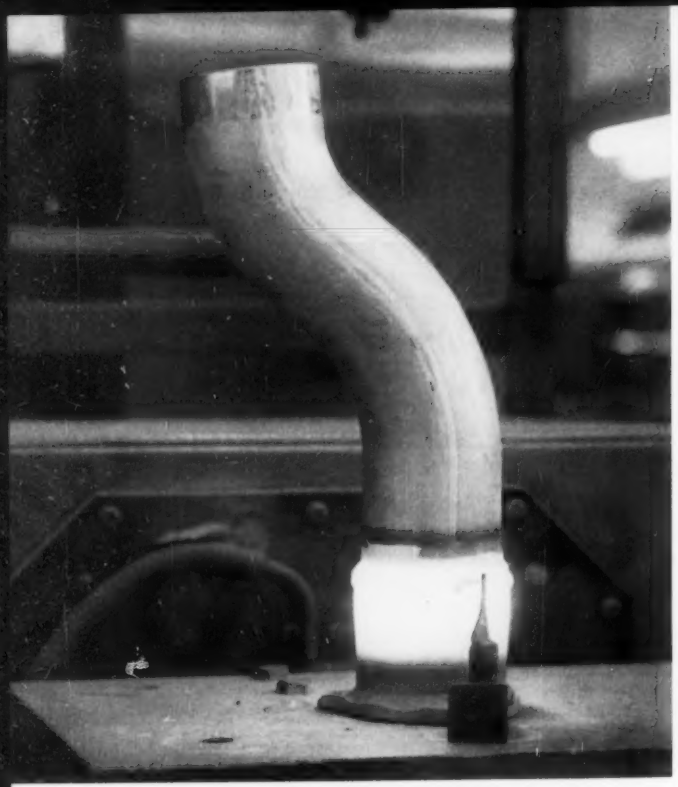


Fig. 8 – 19-9 DL Stainless Manifold Parts Being Brazed With a High-Nickel Brazing Alloy. Special coating allows brazing in air. Induction coil is on inside

Fig. 9 – Rocket Nozzle Built Up in Layers by Plasma-Flame Spraying. Wall composition varies from 100% W (inside) to 100% ZrO_2 (outside)

plicated problems with confidence. Unusual and highly beneficial results may be achieved by combining two or more coating techniques. For example, an exhaust stack – aluminized on the inside and ceramic coated on the outside – provides good oxidation resistance and protection against lead products, carbon and sulphur on the inside, and also reflects heat. The outer ceramic layer provides oxidation and corrosion protection and improves the heat-emission characteristics. This combination of reflectivity on the inside and emissivity on the outside keeps the exhaust manifold much cooler than it would be if it were either uncoated or coated by only one process.

In brazing stainless steel, a carefully controlled inert atmosphere is usually required, but special coating formulations now permit induction brazing in air. This is shown in Fig. 8; stainless steel parts are being joined with a high temperature, nickel-base brazing alloy.

Plasma Arc Spraying

The adaptation of the plasma arc for powder spraying has made it possible to melt (or plasticize) and spray materials having the highest melting points known to man. This capability plus the advantage of atmosphere control during spraying has improved and will extend refractory coating applications.

Defense programs and developments in the aeronautic and astronautic fields have brought about a requirement for materials capable of operating under conditions of high heat flux and high temperature. Requirements for heat shields for satellite re-entry and glide re-entry have posed material problems beyond current technology.

In a typical plasma spray system, monatomic or diatomic gases pass through an electric arc (at 26,000° F.) contained in a water cooled tube. Powder materials are usually introduced downstream of the arc. Here they are melted or plasticized and carried at high velocity by the plasma to the workpiece. Refractory metals, oxides, carbides, nitrides, borides and silicides can be sprayed.

An important byproduct of the plasma arc technique is the potential for tailor-made new engineering materials. Figure 9 shows a tungsten-zirconia rocket nozzle built up in layers by plasma-flame spraying. The composition of the wall varies in uniform steps from 100% tungsten on the inside to 100% zirconia on the outside.

Brazing Shortcuts for the B-58

By D. R. TORGESON
*and J. J. KENNA**

At the Fort Worth plant of Convair, several devices and methods have been developed to lower brazing costs and shorten brazing time of honeycomb panels. Many of these ingenious shortcuts are described in this article. (K8; SS, Al)

IN THE B-58, A SUPERSONIC BOMBER, the wings, fuselage, vertical fin, rudder, and component pods carried beneath the fuselage are fabricated from bonded sandwich panels of aluminum honeycomb. While the fabrication of such structures is a standard practice today, this was not always so. As a matter of fact, in the advance of brazing from a structural concept to a reliable production operation, the first efforts were fraught with many knotty problems. This article will describe some of the difficulties met and solved in fabricating one type of brazed honeycomb structure.

A Typical Part

The engine nacelle panel of the B-58 consists of 17-7 PH stainless steel honeycomb core sandwiched between thin metal skins and contained within Z-edge members. Detail parts are all brazed together with a silver-copper-lithium alloy. High strength and light weight combine to make this structure extremely durable within the operating temperature of the plane.

In producing this panel, we made several modifications and improvements in the brazing operation; they have resulted in reduced time cycles, lower costs, and improved panel quality. A number of these advances were made in tooling. Permanent-type braze forms around the panel – these transmit pressure from box diaphragm to panel – are currently made of Type 321 stainless steel because the thermal coefficient of this steel closely matches expansion of 17-7 PH. For contoured panels, a slotted-type braze form (Fig. 1) allows panel flexibility throughout the brazing temperature range over

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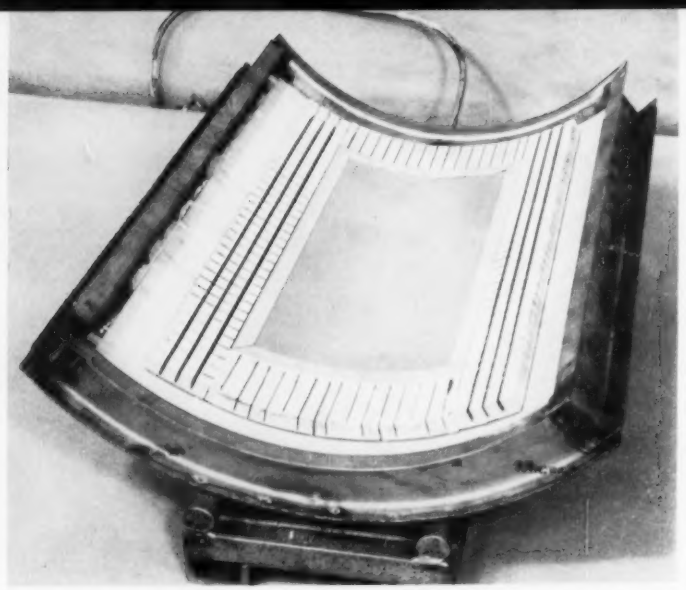


Fig. 1 — Slotted-Type Braze Form. The engine nacelle panel is contoured; the slots in the form allow for flexibility while the form expands and contracts on heating and cooling during the brazing operation

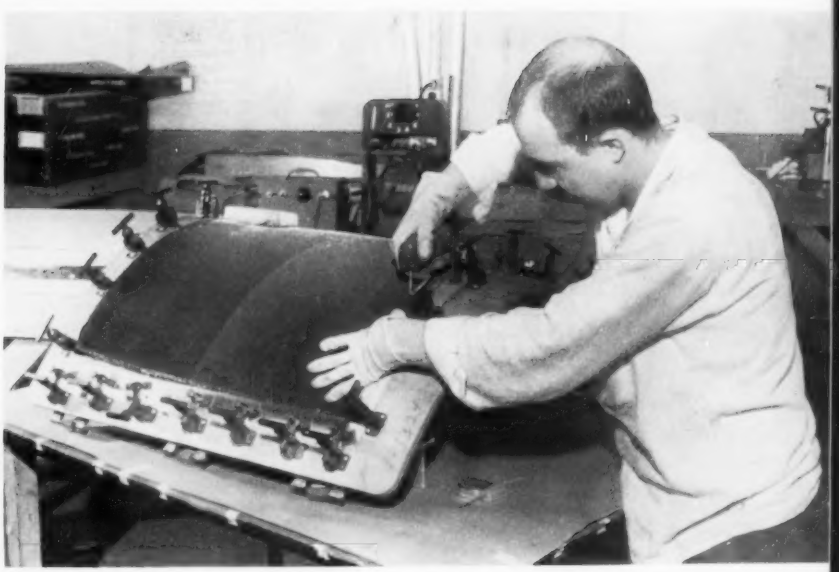


Fig. 2 — Panel Detail Assemblies Are Tack Welded, and Placed in the Braze Box as a Package. This is a typical assembly fixture

the entire contour. It minimizes repair, maintenance, and replacement costs.

Originally, the braze boxes were welded of heavy-gage stainless steel, a thin diaphragm being welded to the top after inserting the panel package. Because of higher labor costs and nonuniform size (coupled with the possibility of panel scrappage caused from weld leaks), a one-piece braze box was devised.

Large wedge panels, about 3 by 6 ft., were originally brazed in all-welded boxes. However, thermal stresses occurred during brazing, particularly around the corner sections; these resulted in severe warping and resultant leaks, a short-lived box and distortion of vacuum sheets on the panel. To correct this, a graphite block was recessed for the panel. The supporting graphite edges prevent distortion of the surrounding sides of the box which would otherwise occur due to thermal stresses during brazing. As a result of this tooling, shop time is conserved and panel quality improved.

Because of the close tolerances necessary between panel components, all panel detail assemblies (complete with brazing alloy) are tack welded together, and placed in the braze box as a package. Reliable tack welding equipment and one-piece lay-up fixtures greatly increase efficiency in this area. Fiberglas fixtures are copper plated in the contact areas to provide convenient backup for the tack weld operation. Figure 2 shows a typical assembly fixture.

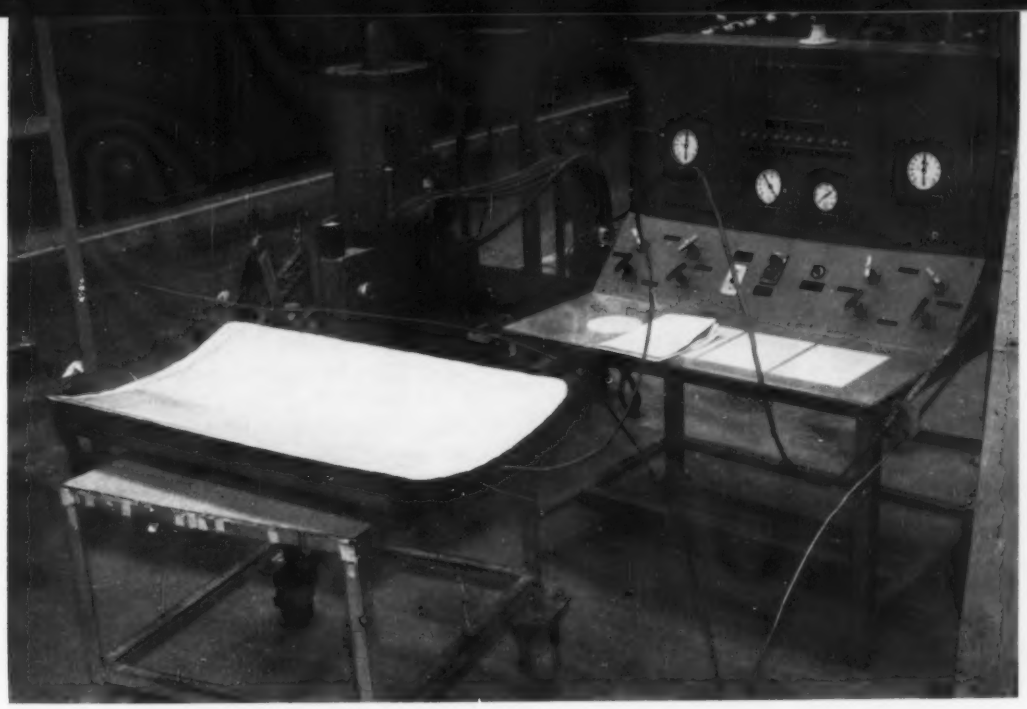


Fig. 3 – Unit for Automatic Cycle Purging. When in operation, this device purges two honeycomb panels at a time. Ten full cycles complete the operation

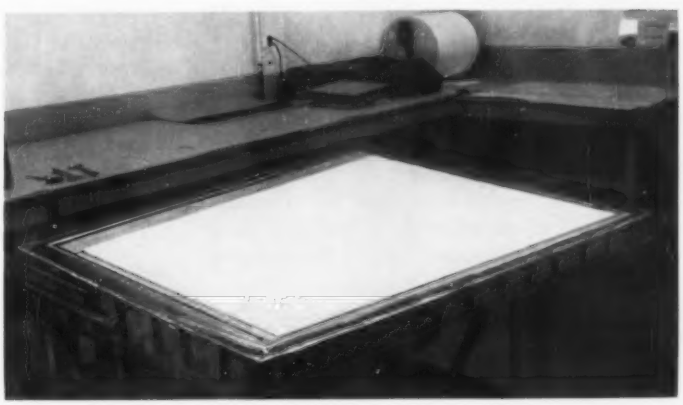


Fig. 4 – "Atmospheric Barrier" Protects Honeycomb Panel From Outside Atmosphere During Brazing. Argon is inside the barrier to protect the panel while a vacuum is pulled outside the barrier. If a leak occurs, the pressure differential will cause the argon to leak out; thus no air can contaminate the braze

Automatic Cycle Purging Saves Time

Operations have improved, too. For example, automatic cycle purge equipment saves much brazing time. Before the equipment shown in Fig. 3 was installed, an operator had to manipulate vacuum and argon valves through the ten separate cycles required to displace air with argon in the honeycomb core panel lay-up. The automatic equipment now enables him to purge two panels at a time. Not only is purging time shortened, but a large part of operator's time can be used for other purposes.

One of our significant developments is the "atmospheric barrier". As illustrated by Fig. 4, this device is simply a fence surrounding the panel in the braze box. Argon gas is introduced within the inside barrier compartment while vacuum is pulled from the surrounding zone between barrier and braze box. When the vacuum sheet is pulled down over panel and barrier, a relatively tight inner compartment is created, establishing a differential pressure between inner and outer compartment. Since a lower absolute pressure is maintained in the outside area of the panel, any leakage which may develop during brazing will allow air to enter this outside region only. Thus, contamination is prevented within the barrier compartment. This device has worked so effectively that, even though the vacuum sheet ripped at a corner over a 1-in. span on one occasion, the

panel braze was bright and unoxidized.

Development of this technique resulted in a further modification of our original brazing procedure, elimination of the furnace retort. Our original gas-fired furnaces for brazing large panels consisted of a large, argon-purged retort into which the individual boxed panels were introduced. The sealed braze box was also argon-purged. Since the barrier technique eliminated the need for an argon atmosphere outside the boxed panel, the retort was eliminated. With only minor modifications in furnace control and external braze box insulation, uniform temperatures were readily achieved over the external braze box surface. Brazing time was reduced by about 70%.

Patch Brazing for Repair

The basic advantage of the brazed honeycomb structure is its high strength-to-weight ratio, which is brought about by the very thin case and skin material. Some of the B-58 panel skins are only 0.005 in. thick and none are thicker than 0.010 in. As a drawback, these thin skins are very easily damaged during handling. They are also vulnerable (after installation on the aircraft) to small stones and other debris thrown up from the runway. To prevent loss of a panel caused by a small puncture or hole, we have developed an oxy-acetylene tool (Fig. 5) which will braze an 0.010-in. thick patch over the damaged area. By using a lower-melting brazing alloy with heat over a localized area, mechanical properties of the panel are satisfactorily retained.

The conventional TH 1050 heat treatment of 17-7 PH stainless steel (recommended by Armco) calls for an austenite conditioning step at 1400° F. for 90 min. Through extensive testing, we found that direct cooling from the brazing temperature of 1650° F. produced adequate mechanical properties in brazed 17-7 PH panels regardless of whether the 1400° F. step was retained or eliminated. Without the 90-min. treatment at 1400° F., about 2 hr. furnace time are saved on each panel. The current furnace brazing cycle, which allows adequate time above 1400° F., eliminates this step.

Inspection Is Simplified

Short cuts in inspecting stainless steel brazed panels have come about through improved production tooling and increased reliability. Expensive X-ray inspection has been gradually reduced by fluoroscopy examination. Over-all inspection costs have been reduced since the start of the brazing program by almost 10 to 1.

These are only a few of the cost-saving devices and methods developed throughout the B-58 program. Through such research and development work as this, much time and money are conserved. In the end, less of our taxes go toward nonessentials, and the planes for our defense reach the runways sooner.

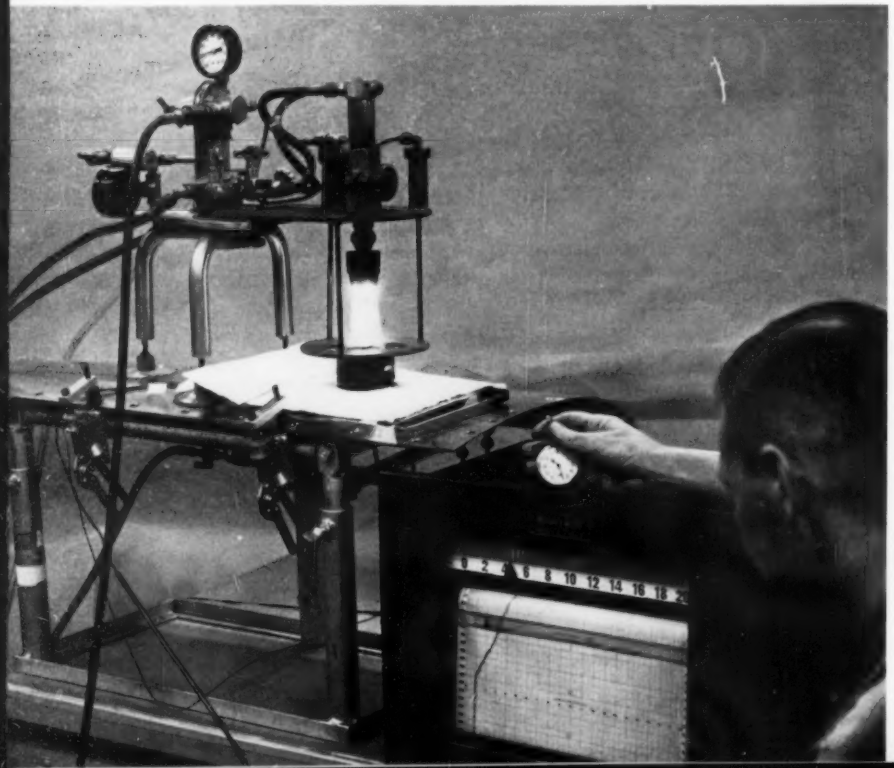


Fig. 5 – Patch Brazing Unit Repairs Damaged Honeycomb Skin

Prizewinner in 14th Annual A.S.M. Metallographic Exhibit

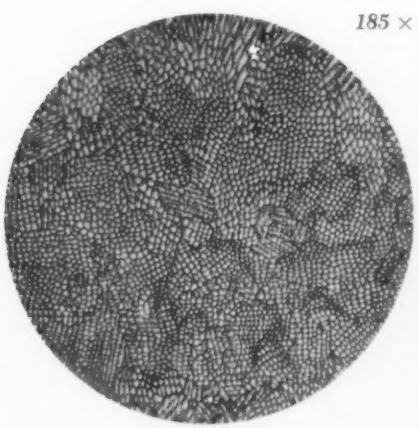
Welding Stainless by Electron Beam

*By C. R. LEHMANN and E. G. LITTELL**

THESE INTRIGUING MICROSTRUCTURES (reduced from the original) were made with one pass of an electron beam. No filler material or special joint preparation was used. As for preparation, conventional metallographic grinding and lapping procedures were followed. Preliminary polishing was done with coarse, medium and fine diamond compound, and polishing was completed with Linde "B" alumina oxide. For the final step, the specimen was etched in dilute superoxol (35 cc. HCl, 15 cc. H_2O_2, mixed into 50 cc. H_2O).

To our knowledge, the structure is unique. From the fusion line inward, the dendritic structure is oriented in a columnar manner. In the center, equiaxed crystals with a more random orientation have formed. An interesting phenomenon is the sharp dividing line between the weld zone and the parent material. The heat-affected zone is virtually nonexistent, and the weld is exceptionally clean.

*Metallographer, Applied Research Operations, and Forming Engineer, Solid Rocket Cases, FPLD Rocket Engine and Test Operation, respectively, General Electric Co., Evendale, Ohio.



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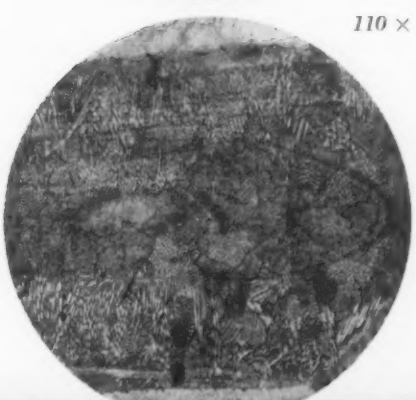

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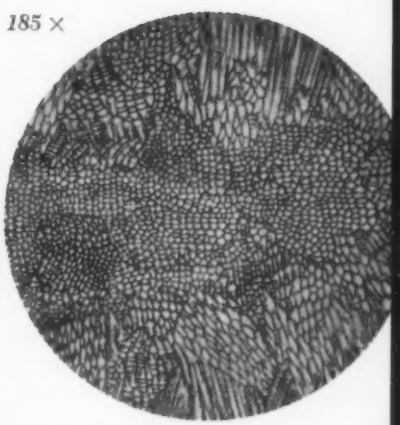

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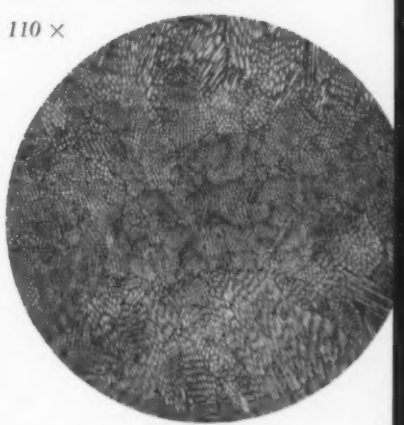

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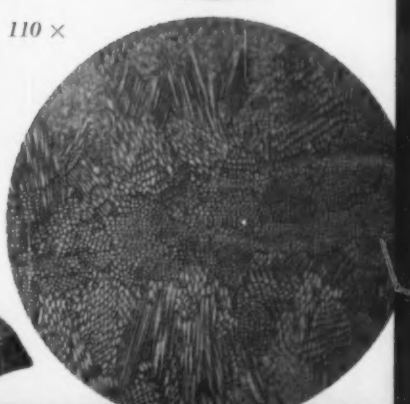

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Brazing Ceramics to Metals

*By LEON LERMAN**

Two methods, the "molybdenum-manganese" and the "active alloy," have been devised for joining ceramics to metals. This article describes the characteristics of each method, including formulations and test data. (K11b, K8)

ONE RESULT OF THE RIGID STANDARDS required of equipment used in the nuclear and missile fields has been a shift from glass to ceramics in radio tube assemblies. Ceramics are an improvement over glass for several reasons. To name a few, they have high bake-out temperatures, greater strengths, and higher dielectric properties. Since these advantages seem to be the answer to the sterner specifications now required in electronic tube industries, manufacturers will undoubtedly use more and more ceramic-metal seal assemblies.

Today, the high-alumina ceramics are the most commonly used in ceramic-metal assemblies for service at high temperatures. There are many techniques for producing the assemblies, each company having its own variation. All methods have one factor in common — a need for clean surfaces. Metalized coatings adhere satisfactorily only to clean surfaces; residue from contaminants may affect the completed tube by gassing during exhaust and life; and stains from finger prints, grease and the like may cause electrical leakage and objectionable appearances. As an additional benefit, the cleaning chemicals usually roughen the surface as they clean it; this helps the metalized coating cling better. Before being cleaned, ceramic parts should be inspected for any flaws

Fig. 1 — Tensile Test Specimens of Ceramic Being Metalized. The metalizing, done either by the molybdenum-manganese or the active alloy process, acts as a "glue" for the metal and the ceramic

*Branch Head, Chemistry, Metallurgy and Ceramics Laboratory, Sylvania Electric Products Inc., Mountain View, Calif. The author thanks Walter Ludewig, Donald Bradbury, Fred Marinaro and Al Ruhrmann, members of the chemistry, metallurgy and ceramics department of the Mountain View Components Laboratory, for their efforts and cooperation in the preparation of this paper.

with some sort of a penetrating indicator. Fluorescent dyes, for example, can be used to locate cracks that are not visible.

Methods for Metalizing

At this point, the ceramic is ready to be metalized (see Fig. 1) either by the molybdenum-manganese† method, the active alloy method, or some variation of either. The most critical factor in making a sintered seal occurs in metalizing the ceramic. Various laboratories differ as to the most desirable size for the metalizing powder – particle sizes ranging from 5 to 90 microns have been successful. Whatever the size used, however, particles should be uniform. Though parts can be sprayed with the suspension, most of them are painted. Thickness of the coat should be 0.001 to 0.002 in.

The sintering temperature ranges from 1300 to 1600° C. (2375 to 2900° F.) depending on the type of ceramics that are used. It is generally believed that the coating should be sintered to within about 100° C. (210° F.) of the deformation temperature of the ceramic. The metal will enter into the structure of some of the crystals of the particular ceramic, resulting in a good sintered seal. High alumina bodies are generally sintered in a range of 1450 to 1600° C. (2650 to 2900° F.) depending on the alumina content of the body.

Some Theory

Previous work has indicated that adherence results when metal is heated in contact with a ceramic during application of a load; the degree depends on the composition of the two materials. The reactions which occur can be divided into three categories: *(a)* formation of a new phase at the interface, *(b)* corrosion of the ceramic by the metal *without* the formation of a new phase, and *(c)* marked penetration of the ceramic grain boundaries. The nature of the materials determines the type of furnace atmosphere to use for the best wetting and adherence.

†A molybdenum-manganese mix generally consists of 80 to 90 wt.% of −325 mesh molybdenum powder and 20 to 10 wt.% of −325 mesh 99.9% pure manganese. Into a 1-qt. ball mill, which is filled to one-third of its volume with ¼-in. flint pebbles, add 400 g. of the molybdenum-manganese mix plus 106.8 cc. amyl acetate "Purified" Grade, plus 53.2 cc. Raffie Swanson No. 5285 lacquer. The charged mill is rolled at 70 rpm. for 48 hr.; then, the material is removed and stored in clean glass bottles on the rolling mill.

Table I – Tensile Tests on AL 300 Ceramic

Material Brazed	Sintering Temperature	Average* Psi. for Set
0.015-in. copper sandwich CuAg eutectic braze at 820° C.	1550° C.	15,020*(d)*
0.015-in. Kovar sandwich 35-65 AuCu braze at 1025° C.	1550	11,390*(d)*
0.008-in. Mo sandwich 35-65 AuCu braze at 1025° C.	1550	9060*(c)*
Ceramic to ceramic 35-65 AuCu braze at 1025° C.	1400	3000*(a)*
	1450	4000*(b)*
	1500	6690*(a)*
	1550	5200*(b)*
	1660	7080*(a)*
Ceramic to ceramic CuAg eutetic braze at 820° C.	1400	7620*(b)*
	1450	7540*(e)*
	1500	8040*(a)*
	1550	10,635*(d)*
	1600	10,280*(b)*
Ceramic to ceramic CuAg titanium braze at 900° C.	No metalizing	6520*(a)*
Ceramic to ceramic Nickel-titanium braze at 1020° C.	No metalizing	7210*(b)*
Nickel plate, not sintered CuAg eutectic braze at 820° C.	1550	11,980*(d)*

*Initial code indicates average of a number of tests: *(a)* two; *(b)* three; *(c)* four; *(d)* five; *(e)* seven.

Certain requirements must be met to produce adherence and satisfactory bonds: The ceramic should have a eutectic bond which melts at 300° C. (540° F.) or more below the deformation point of the ceramic as a whole and about 200° C. (360° F.) below the metalizing temperature; the brazing material should melt below the melting point of the ceramic's lowest melting eutectic; neither the brazing material, nor any alloy formed between it and the metal component, should alloy with the metalizing metal; the brazing material should flow plastically under stress before the tensile strength of the ceramic is exceeded; last, the furnace atmosphere should contain about 0.25% oxygen so that a trace of molybdenum oxide forms.

At the sintering temperature for the metalizing material, the molybdenum particles are wetted by the liquid eutectic constituent in the surface of the ceramic. During cooling, the eutectic liquid should solidify completely to a uniform crystal structure which is free from

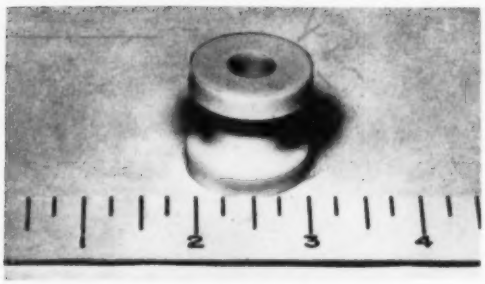


Fig. 2 – Tensile Specimen for Testing Ceramic-Metal Bonds

residual glass so that the molybdenum particles are locked within the crystal rather than in a glass flux.

To demonstrate the complexities involved in establishing adherence mechanisms, consider the reactions occurring as molybdenum-manganese mixes are heated. At about 800° C. (1470° F.) the manganese is completely oxidized to MnO in a hydrogen atmosphere of −85° F. dew point. Next, the MnO agglomerates and attracts the molybdenum particles at around 1000° C. (1830° F.) With the formation of spinel ($MnAl_2O_3$) at this temperature, there is some solid-phase interaction, but the bond between the metal and ceramic is very weak. (In fact, the metal is usually rubbed off.) The reaction proceeds with continued heating to 1200° C. (2200° F.) with an appreciable amount of liquid forming at the interface. (The temperature at which this will occur will vary with the type of ceramics.) With continued heating to 1300° C. (2370° F.) the reaction between the MnO and Al_2O_3 progresses, and at 1400° C. (2550° F.) the molybdenum particles sinter to form a continuous layer. The best bond correlates with the most extensive glass development at the ceramic metal interface.

As the composition of the ceramic is changed (or the composition of the metalizing metal, or the processing conditions), the entire sequence of reactions changes. However, some common features seem to hold wherever there is adequate adherence. These include: *(a)* a controlled degree of oxidation of the metal, *(b)* chemical reaction between this metal oxide and the ceramic to form an interface zone, and *(c)* bonding of metal and ceramic through this interface in a graded, continuously coherent structure which is physically compatible with the ceramic.

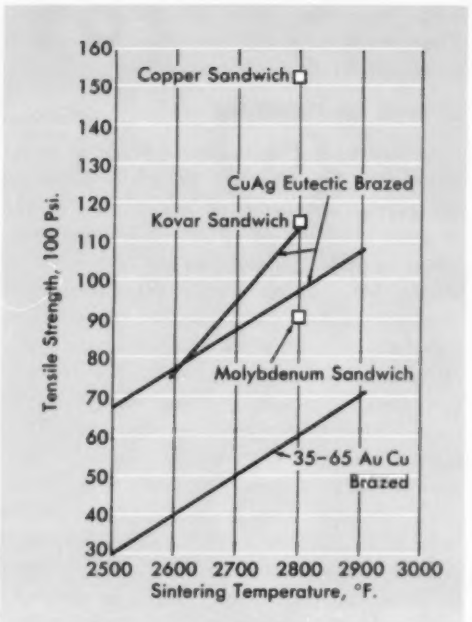


Fig. 3 – Results of Ceramic-Metal Bond Tensile Tests

Much of the difficulty which has arisen in attempting to mass produce ceramic-metal soldered seals has been because of the two-faced nature demanded of the metalized coating. It must be oxidized on the side being joined to the ceramic, yet be metallic on the side to be wetted by solder.

After the molybdenum-manganese is sintered, the surface is nickel plated. Then, the ceramics are again sintered at 900 to 1065° C. (1650 to 1950° F.). The ceramic is now ready to be assembled to a suitable metal component.

Factors in Choosing the Metal

In considering the types of metal to be used, it is best to choose a metal which will closely match the thermal expansion of the ceramic. However, this is not always possible. Even if a metal with a similar expansion coefficient were used, this in itself would not guarantee that there would be no failures due to temperature changes. To illustrate, during the second brazing, there is a temperature gradient between the outer metal and the ceramic (due to the lower thermal conductivity of the ceramic). This would cause the metal to expand away from the ceramic, and the resulting tensional stresses can produce failure. Therefore, it is preferred that the *(Continued on p. 134)*

Producing for the New Technologies

Inspecting Jet Engine Parts With Eddy Currents

*By R. L. LIPE**

Periodically, turbine wheels in jet engines have broken, resulting in accidents costly in both aircraft and lives. The need for a test which can detect defects at the operating base level before they cause such failures has been met by the portable eddy current tester described in this article. (S13h, Q3q, T7h)

IN A PAPER PRESENTED at the 18th Annual Meeting of the Society for Nondestructive Testing, Maj. Gen. Joseph D. Caldara made the emphatic statement, ". . . an area which has been most perplexing and troublesome is with the turbine wheel of the engine". Experience in the Air Force has certainly shown this to be true; various failures at critical moments have caused the loss of aircraft, lives, and vast funds. Subsequent investigations showed that, in one type of engine, failures were of the serration type – a small chunk (or chunks) broke loose in the blade retention area. In another engine, turbine wheels failed in a segmented manner – a large section of the wheel broke away. These failures have been attributed to higher than normal thermal cycling, intergranular oxidation in the bottom of broached areas and lowest serrations, and inclusions found throughout the failed areas. Such defects can initiate stress-rupture cracks which eventually progress into a serration or chunk breakout failure.

In these engines, then, the problem is to find the cracks before they cause failure. Until recently, we have employed fluorescent penetrant methods for this work, but have found them to be limited in some respects. (As an example, if a crack is covered with flowed metal or filled with oxide, it cannot usually be detected.) Because of this drawback, we have

*Service Engineering Div., Oklahoma City Air Materiel Area, Tinker Air Force Base, Okla.

been experimenting with other nondestructive tests, notably a portable tester* which employs eddy currents. After much work, we feel we have devised an adequate instrument for detecting cracks underlying paint, oxides, embedded inclusion, and flowed metal.

Details of the Instrument

Theoretically, eddy current testers operate through the "similarity" law, which states: "Geometrically similar discontinuities (such as cracks with specific depth and width measured in percentage of material thickness) will produce the same eddy current effects and the same variation of the effective permeability if the ratio of the test frequency to the limit frequency is the same." In practical instruments, various methods are used to suppress undesired effects. This is essential because effects caused by dimensional changes and "lift-off" are frequently much larger than those produced by cracks. To cancel out these unwanted signals the "antiresonant test system"† is employed.

*A Magnetest ED-500, modified to detect cracks without interference from extraneous impressions. The instrument was designed as a "go-no-go" gage with minimum adjustment for frequency selection and lift-off compensation.

†U.S. Patent No. 2,939,073.

The instrument uses an arrangement of a self-excited oscillator operating at 200 kc. which is inductively coupled to a half-wave bridge. An antiresonant circuit, consisting of the probe, forms one leg of the bridge. A variable resistive leg, two fixed resistive legs, and a sensitive meter are the remaining parts of the bridge. This system permits an undesired factor to be completely suppressed in the impedance plane.

Under normal operating conditions, the oscillator is fixed at a frequency higher than the material resonant frequency of the antiresonant probe. This unique setting provides a coincidence of two resonant conditions for the probe placed on the metal and at some distance (0.006 to 0.008 in.) away. In this way, effects of rough oxide or dirt-covered surfaces may be suppressed and parts can be inspected directly.

Compensating for these undesired effects has a strange consequence. When the test coil is placed on the specific part or removed entirely, the needle does not flicker at all. As soon as a crack is present in the metal below the test coil, however, an indication is obtained. Thus, the test coil can be moved rapidly and without special care over the surface of a metal.

After devising this new instrument, we tested it thoroughly, comparing its findings with those from fluorescent penetrant tests. Method, technique and instrumentation were all tried under every known condition which might produce incipient failures.

A scrutiny of recorded data would be required to fully realize the potential of this new

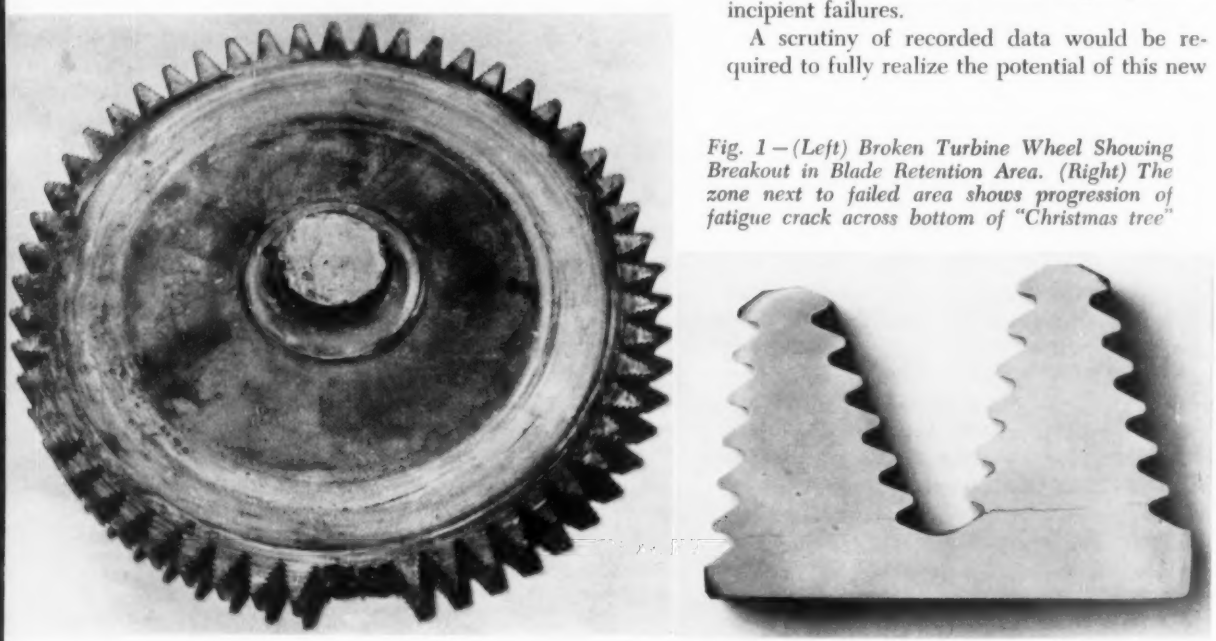


Fig. 1—(Left) Broken Turbine Wheel Showing Breakout in Blade Retention Area. (Right) The zone next to failed area shows progression of fatigue crack across bottom of "Christmas tree"

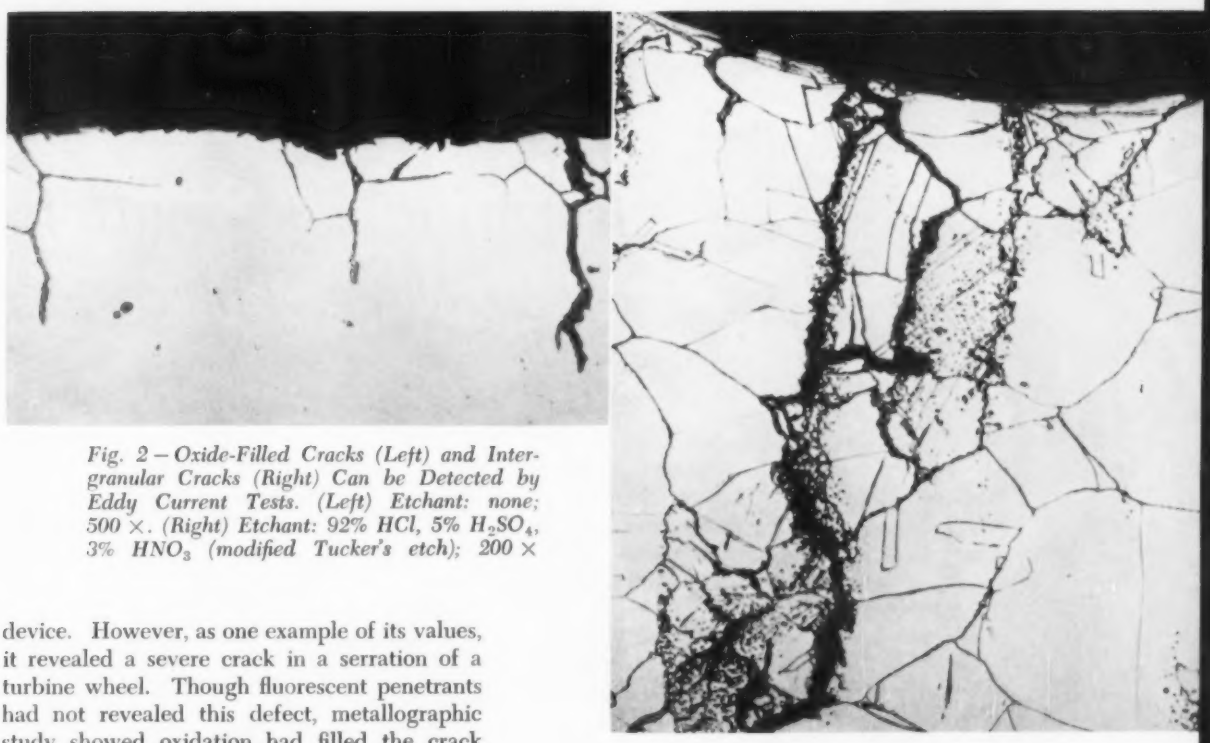


Fig. 2 – Oxide-Filled Cracks (Left) and Intergranular Cracks (Right) Can be Detected by Eddy Current Tests. (Left) Etchant: none; 500 ×. (Right) Etchant: 92% HCl, 5% H_2SO_4, 3% HNO_3 (modified Tucker's etch); 200 ×

device. However, as one example of its values, it revealed a severe crack in a serration of a turbine wheel. Though fluorescent penetrants had not revealed this defect, metallographic study showed oxidation had filled the crack which had only recently grown from intergranular oxidation.

These successful laboratory studies prompted service tests which were used to develop the instrument's simplicity and "go-no-go" characteristics. In most instances, eddy current tests of numerous turbine wheels correlated with fluorescent penetrant tests. However, there were also occasions where wheels had been condemned unjustly by the penetrant method (penetrant indications of cracks were actually caused by lines of pits due to intergranular oxidation). When the eddy current instrument indicated the wheel to be free of cracks, metallurgical analysis proved that the wheel contained only varying degrees of intergranular oxidation. There was no apparent evidence of rapid progression, and above all, no cracks.

Some of the Problems

In devising this unit, one question of concern was, "What would result if foreign metal were embedded in the part just over the crack where it reaches the surface?" First of all, the cracks are generally about ¾ in. long, 0.020 in. deep and 0.0012 in. wide. We found that even though the crack was completely covered by flowed metal (due to machining), crack detection was not affected.

Another problem area was probe wear, but this has been minimized by selecting the proper material and covering the coil. Also of concern was the possibility that the instrument might give variable results over a long period of time. Consequently, two check points (for standardization and compensation) have been provided within the instrument to insure proper operation. Now, the only service normally required will be an occasional tube or fuse replacement.

All in all, this newly developed eddy current instrument is considered to be a reliable tool and a feasible method for inspecting turbojet engine parts at both field and overhaul levels. This device will indicate cracks which can cause turbine failures even though they are covered over by layers of dirt, oxide, and the like. It will also detect the presence of intergranular oxidation. And as a final advantage, the versatility of the method, instrument and technique enables us to check various parts of several types of engines by designing a suitable probe and establishing requirements for detecting specific incipient failure flaws.

Short Runs

Forming Corrugations to Close Tolerances

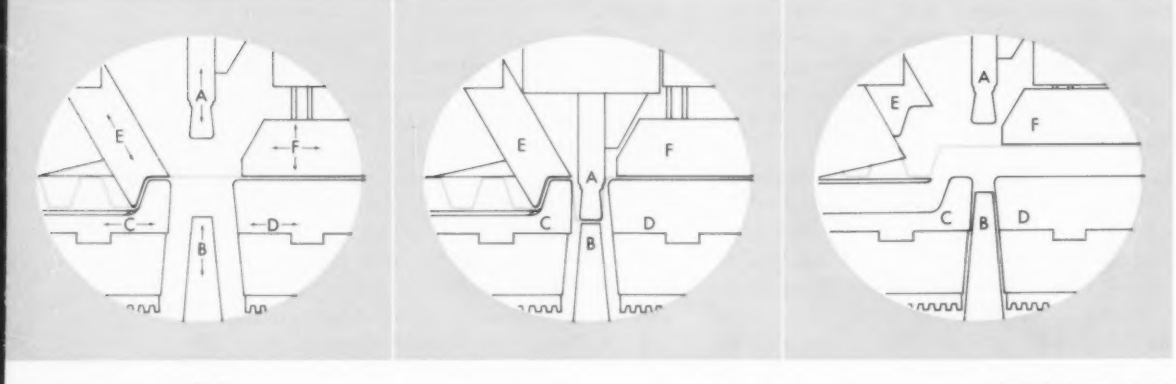
*By ARTHUR MOREFIELD**

ENGINEERS AT BOEING AIRPLANE CO. have developed a new system for forming close-tolerance corrugations. The machine which they have designed and built virtually eliminates the drawbacks associated with conventional methods. Since the machine, which processes sheet 36 in. wide, is completely adjustable to change height, spacing and angularity, it is possible to form a variety of materials, gages, or part configurations with the same set of tools. After settings have been established, the machine can reproduce bends within ±0.005 in. tolerance time after time.

Featuring a clamping and folding method of forming (instead of the conventional drawing and bending), the machine makes pleats one at a time. Figure 1 illustrates the three major actions of the forming cycle. In Fig. 1 (left), the machine has indexed and clamped the exact amount of material required to form one corrugation. Components C and E index and clamp the material in relation to the previous bend, while D and F pull the material taut before clamping. Spacing between C and D is controlled by adjustable stops.

Figure 1 (center) illustrates the next major step. Punches A and B have sandwiched the material and folded it between dies C and D. As punch A moves to force B down, C and D move inward to predetermined index points. These points can be *(Continued on p. 134)*

Fig. 1—(Left) Forming Corrugations in Alloy Sheet. Dies E and C clamp to form the pleat while F and D pull the sheet taut. Arrows indicate die motions. This is the first major step in the forming process. (Center) In the next forming step, dies A and B move down to form the next corrugation, and F and D move toward E and C. (Right) When the corrugation has been formed, the dies release the sheet, and F, which contains a vacuum chuck, moves the sheet forward a specified amount. All steps are repeated for each successive corrugation



*Manufacturing Development Engineer, Aero-Space Div., Boeing Airplane Co., Seattle, Wash. The work described here was performed under Contract AF 33(600)39542 sponsored by the Manufacturing Methods Branch of the Air Materiel Command Aeronautical Systems Center.

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Corrugations . . .

(Continued from p. 132)

adjusted to allow for spring-back variations in different materials. Travels of A and B are also controlled by adjustable stops.

Figure 1 (right) shows the completed corrugation. Index clamp E and punch A have been retracted and punch B has ejected the part. Clamp bar F, which is equipped with a vacuum chuck, has advanced the part before indexing it for the next cycle.

A complete forming cycle consists of 17 actions, and requires about 35 sec. to complete. At present, it is controlled by a rotary selector switch, but the whole system could be adapted to automatic operation.

The corrugation-forming machine has successfully formed Type 321 steel, René 41, Hastelloy "X", HS-25 and M-252 to extremely close tolerances. Each of these alloys has a different forming characteristic and also differs in spring back; however the same configuration was fabricated in each by making slight compensations in the adjustable stops. With conventional forming methods, a tool would be required for each material.

When compared to brake forming, tolerances that can be maintained are about five or six times closer, and forming is four times as fast. Index holes, which are required for close tolerance brake forming, are not needed.

Matched die forming is probably twice as fast, but the tolerance that can be maintained is only about one-third as close. Flat areas, or tops of the corrugations, are crowned because the material is drawn over the punch before the bends are set with a matched die. The corrugation machine, however, firmly clamps the flat area before the forming cycle starts and and maintains this pressure throughout the cycle, thus producing a corrugation with flat tops and no die curl or galling marks.

Brazing Ceramics . . .

(Continued from p. 128)

metal ring outside the ceramic cylinder should expand more than the ceramic, while a metal member

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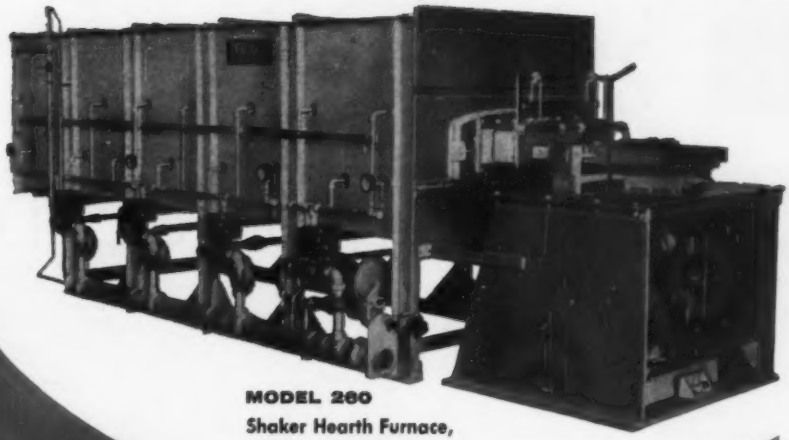

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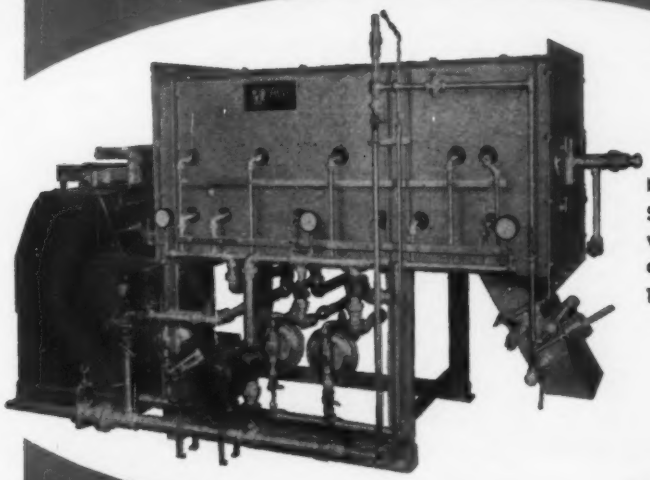

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Circle 1157 on Page 48-S

LETTERS TO THE EDITOR

Got Any Use for Gold?

ARLINGTON, VA.

As pointed out in the item of the above title in December's *Metal Progress* (p. 68), gold's possibilities have been neglected from the standpoint of its alloying effect in minor percentages. In addition, there are doubtless many industrial applications where gold would be economically justified if one took into account its very high scrap value, since the cost of using it would be principally the interest on the investment.

However, the published note is misleading in its implications as to uselessness and as to effect of new uses on the cost.

Actually, gold has a unique combination of properties in the pure state – malleability, ductility, impact resistance, fatigue resistance and corrosion resistance. Furthermore, gold-base alloys are available with a wide range of properties. In short, gold is probably the most all-around useful metal known to man. This, in combination with its scarcity, is what makes it valuable, and its intrinsic value in turn is what makes it useful as the international basis of exchange.

Discovery of new technical uses cannot change the price of gold; this is fixed by Government monetary authorities. One can buy all the gold he needs for *industrial* purposes at the government price, so he would not bid higher in any market. The gold miner, on the other hand, can always sell his gold to the Government at the fixed price. The gold miner works the veins and the deposits justified by the going price of labor, materials, and capital in relation to the price of gold. If there is inflation, he must reduce his gold production because his costs increase and he can afford to work only the richest deposits. Conversely, during deflation he can and does increase production.

The price of gold is bid up only by people who are not eligible to purchase it for industrial or other business uses, and when there is fear of currency devaluation. In effect, they must buy from speculators who really decide what the *currency* is worth, rather than what the gold is worth.

It might well be that new technical uses for gold will be discovered through the very commendable Canadian program. But they will be evaluated on the basis of the going monetary price of gold at the time, just as they are now.

R. CARSON DALZELL

Odd Structure in Tungsten

MENLO PARK, CALIF.

In calibrating the temperature of a reactor to study the behavior of tungsten in the various components of solid-rocket propellant exhaust at high temperatures, we used the melting point of various metals for temperature determination. In this particular instance, a strip of pure tungsten was being run in pure nitrogen at 100 psi. pressure at an uncorrected pyrometer reading of 3000° C. (5400° F). After 1 min., the tungsten strip melted; the micrograph above (taken by W. C. Mitchell at 250 ×) pictures the tungsten surface near the point of failure. Whether this particular crystal structure is the result of melting and subsequent solidification or is some sort of a thermal etch, we do not know. It would be interesting to see what the experts have to say about it.

R. H. THIELEMANN
Chairman
Dept. of Metallurgy
Stanford Research Institute

Steel

Tool Steel Topics

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Re-draw die uses 36 pieces of water-hardening tool steel

This large re-draw die shapes an intricate rear floor pan, made of sheet steel, for an American-made automobile. The die contains 36 pieces of Bethlehem carbon tool steel which serve as wear plates, inserts, keeper blocks, and insert plugs. The 17-ton die was produced in the shop of Modern Die & Tool Co., Utica, Mich.

The wear plates and inserts were hardened to Rockwell C 58-60; the keeper blocks and insert plugs to Rockwell C 50-52. The die maker liked the die for its easy machinability and ease of heat-treatment; the automotive manufacturer liked its resistance to wear and shock, and superior weldability when changes were required.

Due to their controlled hardenability, Bethlehem carbon water-hardening tool steels are ideal for applications calling for high shock-resistance. They are also resistant to wear, and have the toughness to withstand cold battering.

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BETHLEHEM TOOL STEEL ENGINEER SAYS:

"Touchy" Tools Should Be Ground On Edge of the Grinding Wheel

A choice of grinding methods is often available on many types of tools. They can be ground either on the side (face) of a grinding wheel in order to cover the whole area to be ground; or they can be ground on the edge (OD) of the wheel by traversing a number of parallel paths to cover the area selected for grinding.

Where the tools to be ground are exceptionally high in hardness, or if they are made of wear-resisting steels, or if there is a history of sensitivity to grinding cracks, edge-grinding is definitely best. The use of a grinding fluid for effective cooling is also essential.

By grinding on the edge of a grinding wheel, only a small area of the wheel is in contact with the tool at any moment. This permits more effective cooling action of the grinding fluid than when a large area of the wheel contacts the tool.

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Circle 1158 on Page 48-B

Brazing Ceramics . . .

sealed inside a ceramic should have a lower expansion.

"Active Alloy" Process

Another method that is used in making ceramic metal seal assemblies is the "active alloy" process*, a method of metalizing ceramics which does not require the high temperatures of the sintered-seal process. The term "active alloy" covers several processes which employ titanium and zirconium. (Each metal has great affinity for oxygen and can also enter into solid solutions with a number of metals and suboxides.) As ceramics, oxides of titanium and zirconium are highly refractory. Since ceramics in general consist of a number of different oxides, it is plausible that titanium and zirconium will, under the proper conditions, reduce some of the ceramic oxides and combine with the released oxygen as long as active gases are not present. Thus, to make the desired joint, put titanium (or zirconium) in contact with two abutting ceramic surfaces, or in contact with a ceramic part and a metal part.

Since oxygen from the surrounding atmosphere must be excluded, active alloy seals must be made either in high vacuum or in an atmosphere of very pure hydrogen, argon, or helium. Both the active metals and the gases used for protection should be very pure. Another caution — if the brazing operation is performed in a vacuum at such temperatures that the carbonates in an oxide-coated cathode decompose, enough CO_2 can be released to form titanium carbide rather than the desirable compounds necessary for establishing a satisfactory seal.

Frequently, the active metal is applied as a hydride. A paint is made (by mixing the powder with a nitrocellulose lacquer) and applied to the ceramic in a thin, uniform layer, either by brushing or spraying. When the assembled parts are heated to about 900° C. (1650° F.), the hydride dissociates, leaving a

*For a more thorough description see Chapter 14 of "Materials and Techniques for Electron Tubes", by W. H. Kohl, Reinhold Publishing Corp., New York, 1960.

Brazing Ceramics . . .

residue of pure metal on the ceramic. This metal then alloys with the metal next to it, and also enters into a chemical reaction with the ceramic constituents. Thus, a tight bond is formed. Instead of painting the ceramic surface with titanium hydride, a thin washer of titanium can be interposed between the two ceramic parts, or between the ceramic and the metal part. One drawback to this method is that titanium melts at 1710° C. (3110° F.), a rather high temperature. However, by placing another lower-melting metal – silver, copper or nickel – in contact with the titanium, the seal can be produced at a much lower temperature.

Although these and other variations of the active alloy method have been successful, there are conflicting opinions as to its merits. It is very convenient since a complete series of assemblies can be made in one brazing operation, but the inherent characteristics of the end seal material may create some obstacles. Although titanium in the unalloyed state is soft and ductile like most pure metals, its physical properties change rapidly with additions of small amounts of alloying elements such as molybdenum, vanadium, manganese, chromium, iron, nickel, copper and aluminum.

Some Test Results

We have recently completed some preliminary tensile strength tests of a ceramic-to-ceramic assembly and a ceramic-to-metal-to-ceramic assembly in which the sintering temperature of the molybdenum-manganese was varied. For tensile testing, we used the standard A.S.T.M. test pieces as recommended by Committee F-1, Subcommittee V, Section D. (Figure 2 illustrates a typical specimen.) The ceramic material was AL 300, 97% alumina, manufactured by Western Gold and Platinum Co. From the very sketchy number of pieces that we ran (Table I, p. 127), it appears that the tensile strength increases with the increase of sintering temperature. Another interesting feature is that the ductility of the sandwich material is apparently important. This is evident from the very high average reading for copper, the very

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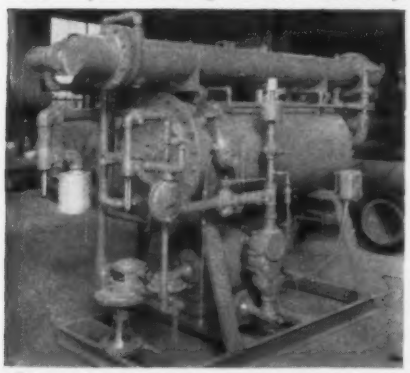

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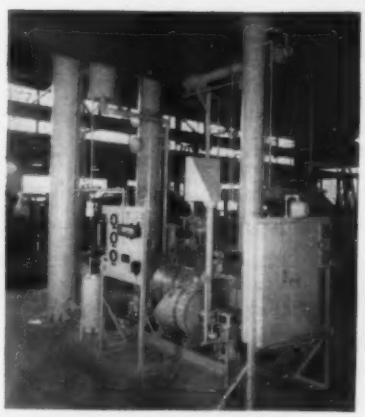

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Circle 1162 on Page 48-B

Brazing Ceramics . . .

low reading for molybdenum and the mid-point for Kovar. As for the active alloys, their average values are below those of the molybdenum-manganese assemblies. However, many more assemblies will have to be tested before we can establish conclusive data.

In conclusion, it is well to remember that the art of metalizing ceramics with gold, silver or platinum is centuries old. The past 30 years have seen that art grow into a science. Great strides have been made by researchers in this field, and our present theories and techniques are a result of their scientific endeavors. Yet, there is still much that can be done. The coming years will see even greater advances.

Bomarc . . .

(Continued from p. 113)

to eliminate the need for conventional bulky and costly welding fixtures. This is accomplished by machining self-aligning edges for the head-to-shell welds. Mating chevron configurations machined at the root of a deep, narrow weld groove fit together, aligning the parts perfectly for welding.

Welds in the helium tank are made by the mechanized tungsten-arc inert-gas process, using helium to shield the top bead and argon to protect the weld underbead. Argon is fed through a hollow tube to a curved metal cup directly beneath the weld puddle to protect the underbead of the head-to-shell girth welds. As the tank rotates beneath the welding arc, this cup remains stationary, thoroughly flooding the underbead with argon in the immediate area being welded. When the final closeout girth weld is completed, the argon tube and cup assembly can be collapsed and removed from the tank through the outlet fitting hole. Weld underbeads protected in this manner with argon flowing in at 40 cu.ft. per hr. are cleaner and brighter than those protected by up to 350 cu.ft. per hr. of helium.

Helium tank welds made with 17-7 PH stainless steel filler wire frequently developed "hot cracks".

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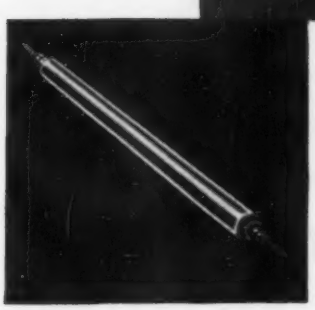
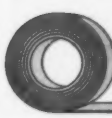




SUPERIOR STEEL DIVISION

OF

COPPERWELD STEEL COMPANY

CARNEGIE, PENNSYLVANIA

For Export: Copperweld Steel International Company, New York

Circle 1164 on Page 48-B

Bomarc . . .

A program undertaken to solve this problem resulted in the use of 13 Cr, 9 Ni corrosion resistant steel filler wire. This wire, introduced into the joint with the stringer-pass technique, has consistently produced high-quality tank welds. It does require, however, that tanks be refrigerated during the heat treatment cycle to develop the necessary mechanical properties.

The boost fuel tank which is mated to the helium tank is made up primarily of rolled and welded shell sections and an aft head assembly. Inserted in the shell sections are longitudinal patches with fitting bosses welded in place. The aft head of the boost fuel tank is conical in shape and is formed by power spinning a heavy 17-7 PH steel blank over a hardened mandrel. Components of the boost fuel tank are joined by square butt welds.

After both tanks have been heat treated, the aft skirt of the helium vessel is welded to the forward, open end of the boost fuel tank. A complete heli-fuel tank is shown in Fig. 6 on p. 112.

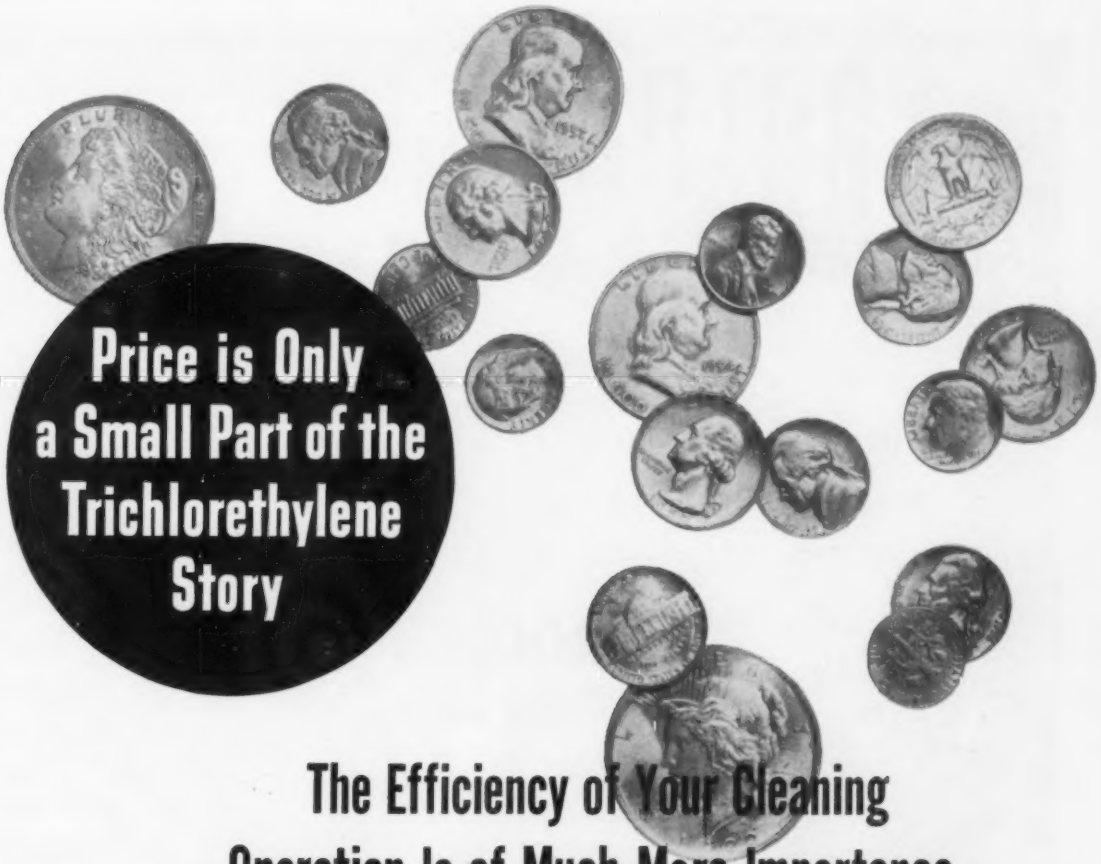
The 17-7 PH boost oxidizer tank is constructed in much the same manner as the boost fuel tank. It has a power spun conical aft head, rolled and welded shell sections with fitting patch assemblies. Its forward end, however, is closed by a draw formed elliptical head.

Rocket Motor Case Improved

The 4330 M steel solid-propellant rocket motor case for the "B" model Bomarc is being constantly improved. Changes in the design of some components have been made to meet demands arising from grain loading and fuel burning; other changes have been made to permit the case to be manufactured more efficiently. Several proposed improvements, currently under investigation, may be incorporated into future motor cases.

The case is constructed of rolled and welded shell and skirt sections, draw formed heads and forged and machined fittings and Y-rings.

Special rings, attached to each end of the case, serve as a means of fastening the case to adjoining missile body sections. The forward body joining ring is welded to the



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Circle 1166 on Page 48-8

Bomarc . . .

motor case; the aft body joining ring is riveted and bolted to the case (Fig. 7, p. 112).

Shell sections are rolled from annealed 4330 M steel sheet 0.140 in. thick. The rolled sheet is trimmed and welded to form 35-in. diameter sections which in turn are butt welded together in rotating positioners to make up complete body shells 10 ft. long.

Heads, welded to each end of the body shell, complete the motor case. Each head assembly consists of a dome welded to a Y-ring which forms the transition from the cylindrical body shell and permits attachment of a skirt section and body-joining ring. The igniter fitting is welded into the center of the forward head and a large fitting to which the rocket blast tube will be attached is welded in the center of the aft head.

All welds in the rocket motor case are also made with the tungsten-arc inert-gas process, using helium gas in the torch and argon to cover the weld underbead. Preweld and postweld heating, once thought necessary for high-quality welds in 4330 M steel, was investigated thoroughly and found unnecessary.

After a motor case is fabricated, but before the body joining rings are installed, it is suspended in a vertical furnace and heat treated to a strength level of 170,000 to 190,000 psi. (Rockwell C-39 to 41). The forward body joining ring is welded to the motor case after both parts are heat treated. This is the only weld which is stress-relieved.

Inspection of the motor case components is rigid in all stages of fabrication. "As-received" material must meet exacting specifications dealing with chemistry, dimensions and mechanical properties. All welds are checked with dye penetrant and are X-rayed. Weld defects are ground away and the part is rewelded. Where necessary body shells are sized on a Grotnes sizing machine to meet close dimensional tolerances. The completed case is checked for aerodynamic cleanliness, fitting face parallelism and concentricity. Local out-of-round areas in the completed case are corrected by shot-peening.

Several proposed improvements,

Bomarc . . .

now under investigation, may be incorporated into future motor cases. Forged and machined heads with integral Y-ring sections and fitting bosses (similar to the head of the helium tank in Fig. 5 on p. 111) are being considered. At this time, cost estimates for this design appear favorable.

Explosive sizing, a new technique with which Boeing is doing considerable development work, may permit further design changes. The motor case shell, fabricated slightly undersize, would be placed in a suitable die, filled with water, and then sized to exact dimensions and concentricity by the force of an explosive charge detonated in the water. With the perfection of this technique, the undersized shell could be fabricated with more liberal tolerances (cutting flow time and expense) and then brought to exact dimensions.

Final Assembly

On p. 113 Fig. 8 shows the Bomarc in one of the final stages of assembly. Tanks, body sections, and the radome are joined with rivets and bolts. Control surface and ramjet engine strut subassemblies are bolted to body frames. Equipment for the various systems is installed and connected by plumbing and electrical wiring. Fairings and other miscellaneous hardware are attached and the missile is painted. The complete missile (Fig. 9, p. 113) is tested to see that all components function properly before being delivered to the Air Force.

Reactor Vessels . . .

(Continued from p. 104)

usually inspected by Magnaflux or dye penetrant before or after cladding or both.

All the above 13 steps and some others are, of course, directed toward the sole end of placing the steel shell in the best possible condition, at the very beginning of its service, to resist subsequent radiation damage. Some of these operations are undesirable from a fabricator's standpoint for various reasons. They all add cost and time. The quenching operation is an especially

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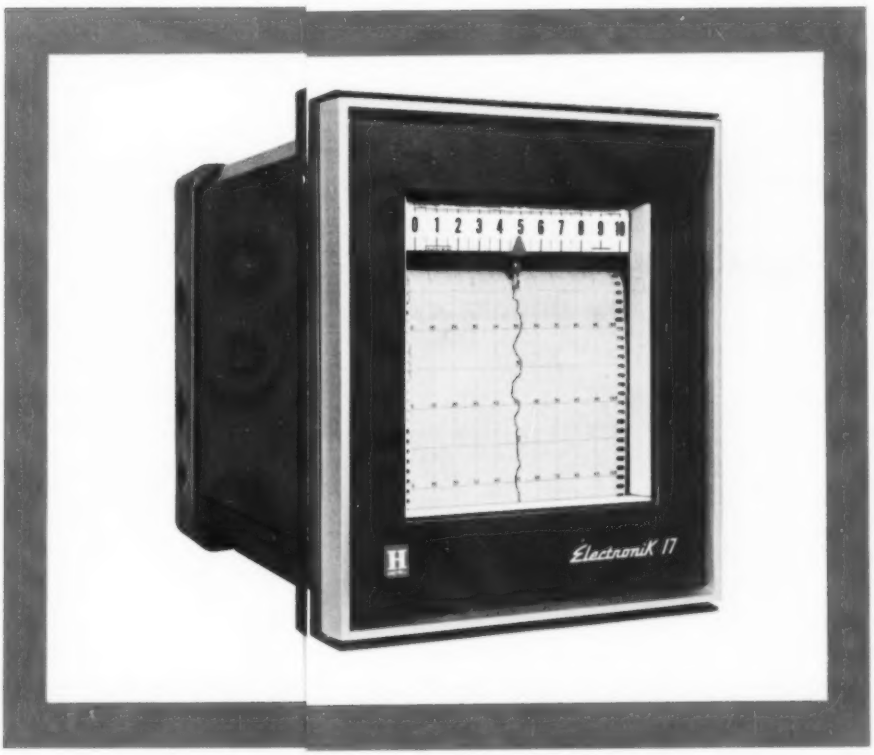

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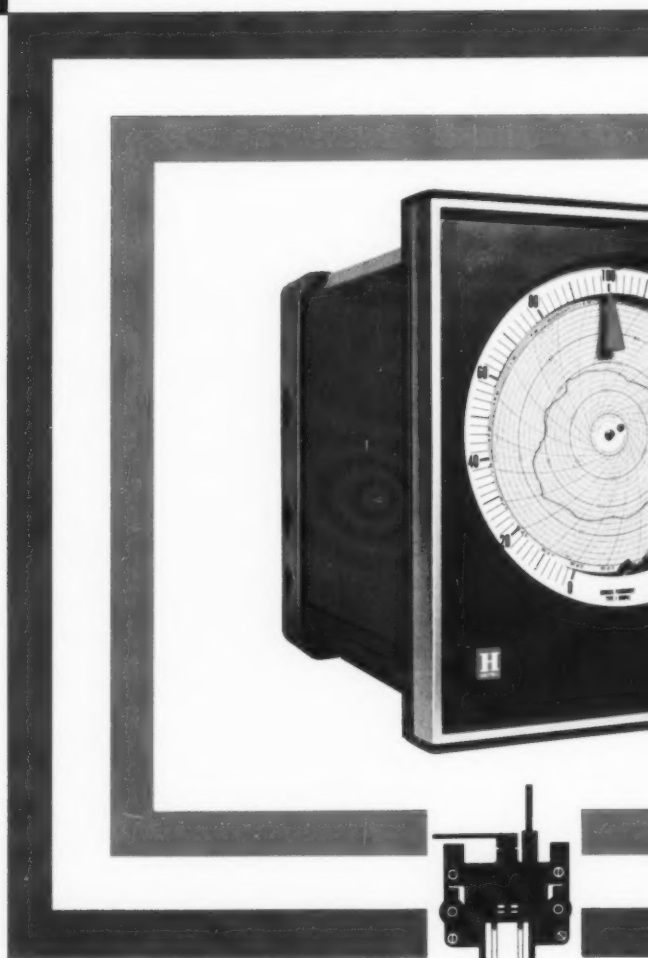

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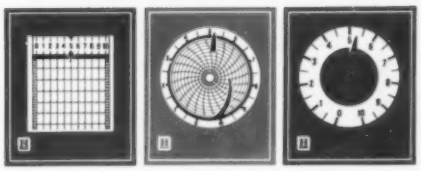

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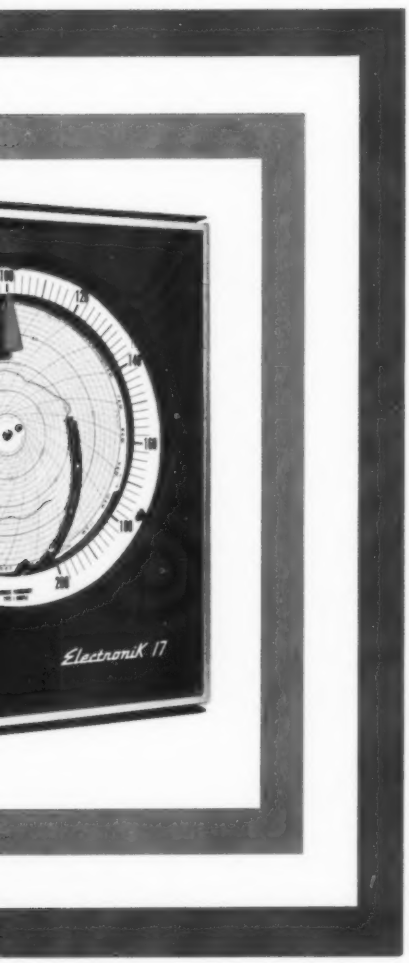

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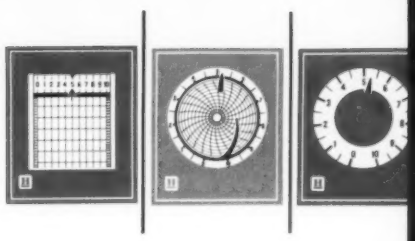

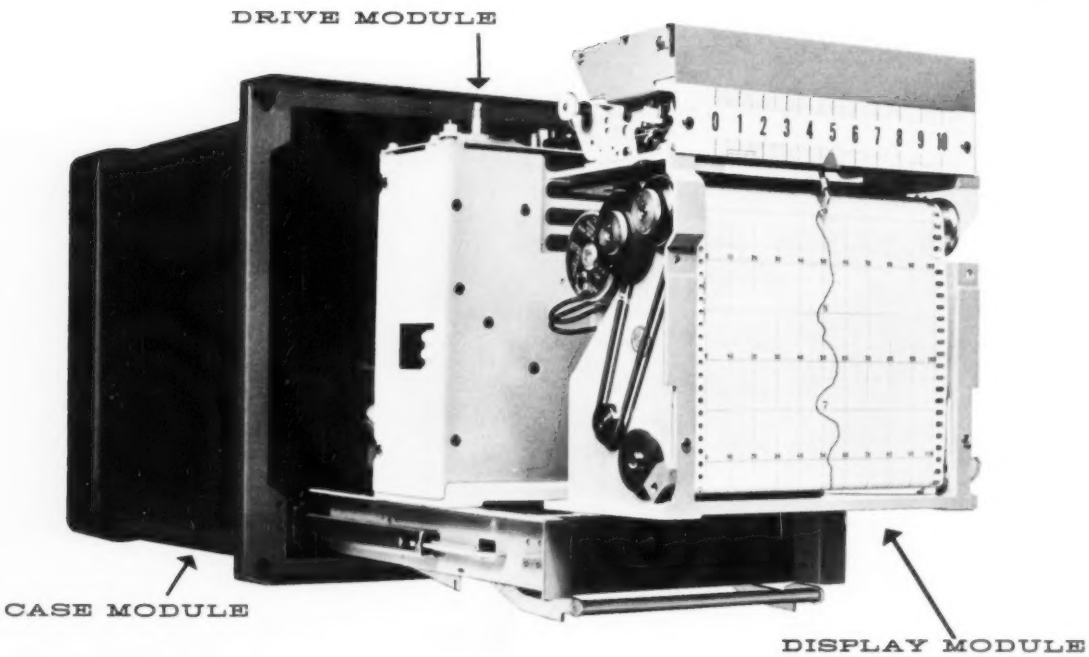

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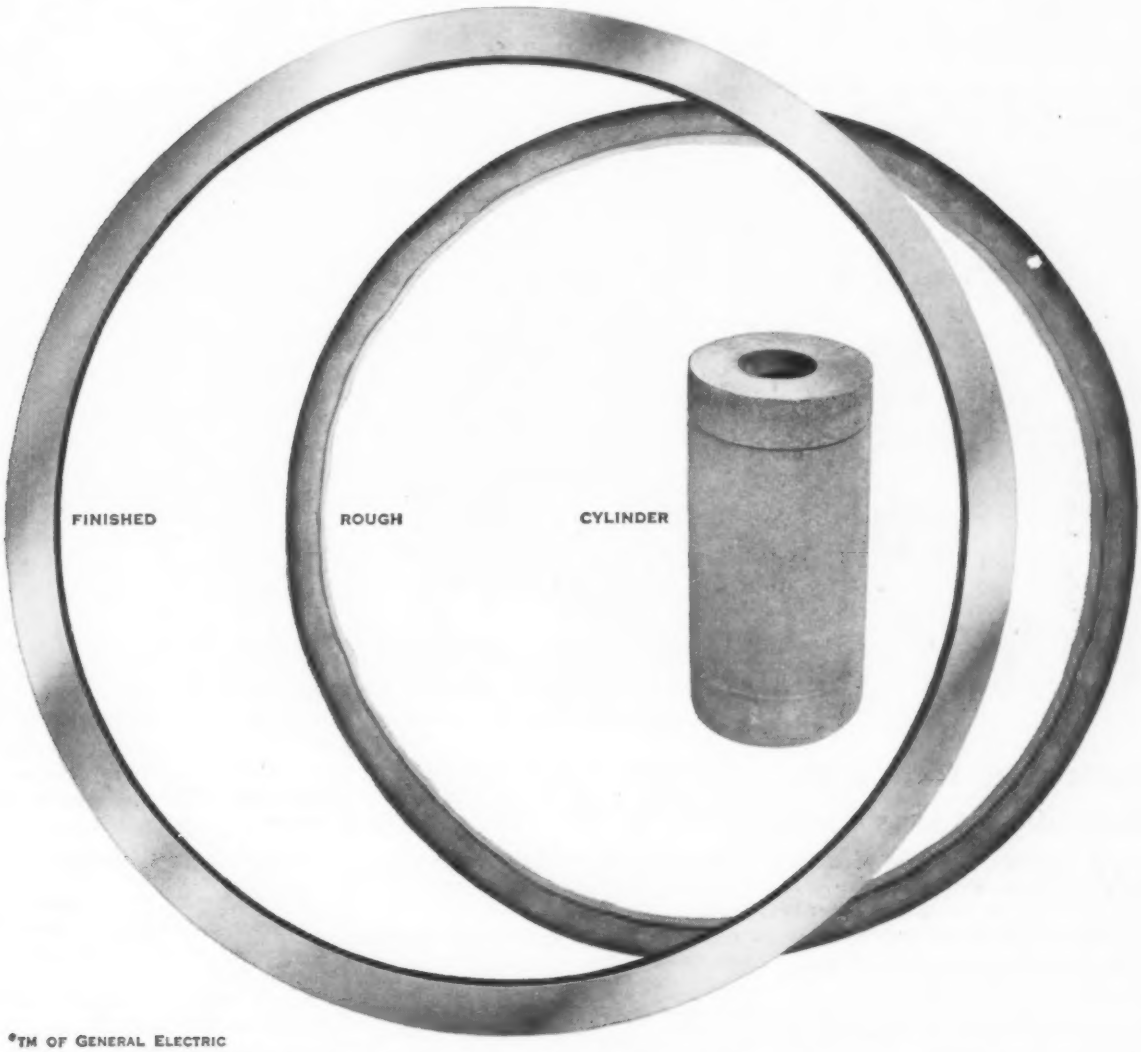

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Circle 1170 on Page 48-B

Reactor Vessels . . .

troublesome one because of the risk of distortion due to unequal cooling rates which can occur if the spray quenching apparatus is not perfectly designed or not very carefully used.

Inspection and Tests

At present there is a trend toward more rigid inspection and closer control of material handling techniques, and there is no reason to believe that this trend will reverse itself. All the information we have indicates that as more tools become available to the metallurgist and the inspector they will be used. The crying need at present is for universally understood and accepted standards to be used when these new and sometimes delicate inspection techniques are put to work in what is essentially a rough-and-ready, heavy manufacturing industry.

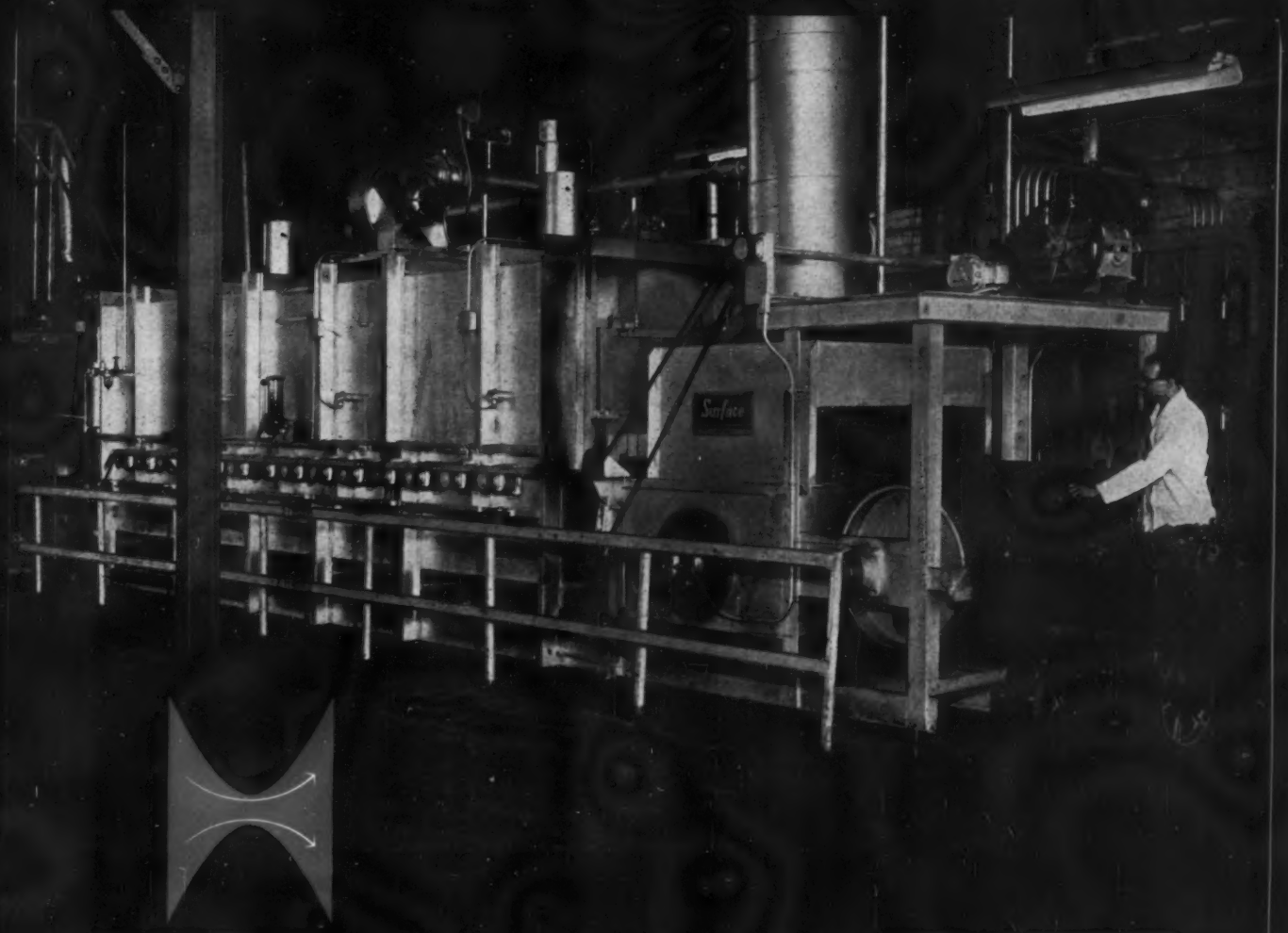
Since so little is actually known about the whole field of radiation damage, it is important that the vessel designer and manufacturer take a good look at the situation confronting them and decide what additional information is necessary to remove the uncertainties with which they are faced. Certainly paramount among the things he would wish to know is the correlation between radiation damage and fatigue life. He has undoubtedly heard a great deal about radiation damage as it affects the impact resistance (Charpy V-notch tests) but he has almost no quantitative information on changes in the fatigue strength.

In connection with this, a bit of caution should be injected: Reactor vessels using carbon steels for the shell commonly use plates between 5 and 9 in. thick. With radiation damage affecting the material the way it does, it may be found that discontinuities in the interior of the steel are of much more importance than has been imagined. For this reason, we should hesitate to extend fatigue data from small irradiated specimens commonly used in laboratory tests because they may not be representative of the thicker plates we are using.

The data obtained from irradiated test pieces to date do not give a clear picture of the effect on properties of exposure at or near the operating temperatures of most pressurized water reactors — say in the range between 475 and 550° F. It is important that sufficient samples be exposed to radiation at temperature while under load to define the effects of this additional variable.

Laminations in Heavy Steel Plate

Before leaving the discussion of properties, there is another important point which should be brought out, namely, defects. A significant percentage of the raw material used in the heavy fabricating industry contains defects of one type or another. Porosity, laminations, and slag inclusions commonly plague those of us who have dealt with heavy metal sections. I personally believe that this is something which can be corrected without further research or development work. Methods are known. What delays progress is



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Circle 1172 on Page 48-B

Surface

A division of Midland-Ross Corporation

MR

Reactor Vessels . . .

that large capital investments are needed to install the electric furnace capacity and vacuum casting equipment in the heavy plate mills. It is fortunate for the nuclear industry that other large steel consumers also face this problem. The need for cleaner, finer-grain steels, free from laminations, has been growing steadily in recent years. It is certain that, as this demand continues, the needed facilities will be installed. The important thing to us, however, is that the need of the nuclear industry is acute; therefore, it is vital to us that the steelmaking facilities be improved as rapidly as possible.

Frequently during this discussion, the importance of field experience was stressed. This point is so vital that it can't be overemphasized. It is unfortunate that it will be virtually impossible to inspect reactor vessels during their service lifetime. Certainly one would not expect to cut boat samples from the interior of a reactor vessel for laboratory examination, nor is it wise to take drillings from the outside. The best way of obtaining this necessary information would be to hang a number of test samples inside the vessel itself. If these were located properly, removed at stated intervals and examined, they should supply a continuing check on the condition of the main structure.

The possibility of annealing to remove the effects of radiation damage is certainly intriguing. If this can be done at a relatively low temperature, it will go a long way toward eliminating the entire problem. While the difficulties of providing for low-temperature annealing will be manifold, they are small in comparison to the alternative of limiting the usable lifetime of a reactor vessel to a few years. Low-temperature annealing can certainly be done, and the job will be much easier if proper provisions are made in the design of the plant at the outset. Of course, with this are associated a number of other questions such as, "What is the effect of further irradiation on material which has been annealed to remove the effects of radiation damage?" We probably won't know the answer to this question for some time, but a lack of foresight in this regard can

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Circle 1174 on Page 48-B

Reactor Vessels . . .

be very expensive to a company which expects a 20 to 30-year return on a considerable capital investment.

Recommendations

The general radiation damage picture may look extremely dark at the moment, but there appear to be several rays of sunshine to keep us from getting discouraged. The important thing is that we recognize quickly what our problems might be and spend the time and effort necessary *now* to develop ways and means to get ourselves out of trouble later. The need for further research and testing in the field of material properties is obvious. The following recommendations involve action which can be effective in a short period of time, based on a commonsense approach, and with the objective of avoiding some of the consequences of ignorance:

1. Install samples of representative materials in operating reactors in locations and under conditions which duplicate the service conditions of the reactor vessel itself.
2. Intensify efforts to obtain the best possible quality of steel which will be used in critical areas of the reactor vessels.
3. Watch design details very closely to make sure that no abrupt changes in cross section are placed in intense radiation fields.
4. Place top priority on testing programs designed to explore the effects of annealing at low temperatures as a means of wiping out the damaging effects of radiation.
5. Pursue a vigorous program to determine the fatigue properties of irradiated steel.
6. Standardize methods of testing and reporting.
7. Publish on a regular schedule the results of current investigations which will contribute to a wider understanding of the radiation damage problem.

Machining . . .

(Continued from p. 100)

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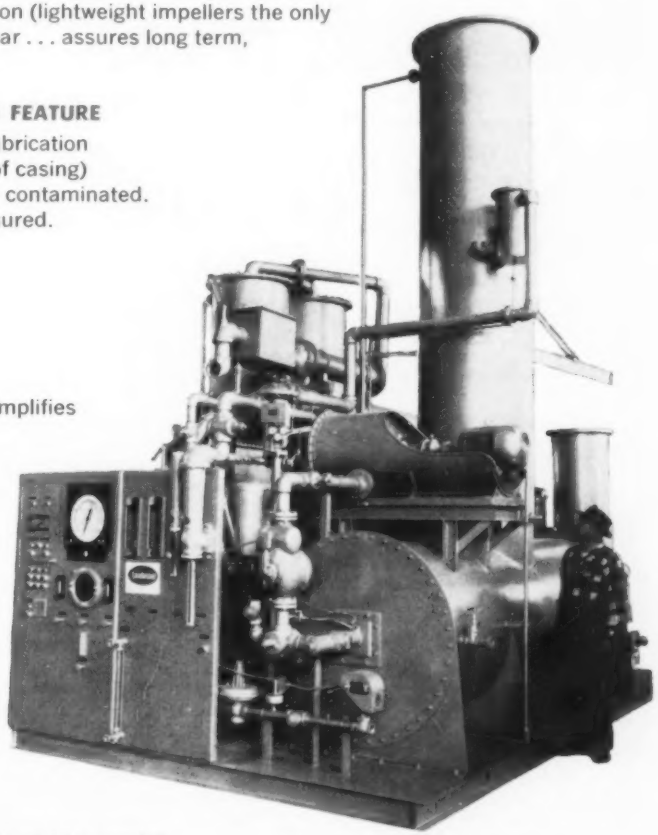

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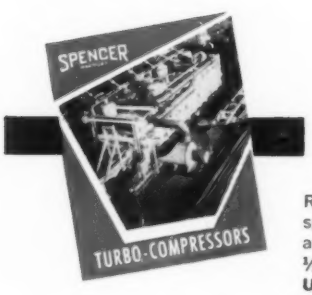

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Circle 1176 on Page 48-B

Machining . . .

ening. The cutting edge should be honed slightly to eliminate feather edge.

Generally speaking, carbide tools are better for machining superalloys than are high speed steels. When high speed tools are used, the cobalt-bearing, heavy-duty types are superior to the all-purpose grades.

The ability to machine superalloys hinges on tool geometry. Tools are generally ground with a zero to slightly positive back rake (usually zero to three degrees), and with a positive side rake up to six degrees. A negative back rake is effective when the tool needs additional edge strength to prevent tool breakage. It is useful where maximum production is the prime consideration. A minimum nose radius will reduce the possibility of work hardening by lowering the tendency to chatter.

For rigidity, tool overhang, the distance that the tool projects out of the holder, should be kept as small as possible. Otherwise, the tool bit is likely to vibrate, chatter and eventually break. Ragged cuts also will result.

In machining, coolants are essential, heavy sulphur-base or sulphur-chlorinated cutting oils being generally preferred. Soluble oil emulsions (used highly diluted) will increase the rate at which heat is removed from the cutting edge of the tool. Carbon dioxide has been used successfully for certain machining operations on some high-temperature alloys.

The depth of cut should be as heavy as possible to avoid glazing or burnishing. In turning operations, this depth can vary from as little as 1/64 in. to ¼ in. It is also important, when removing metal, to get under the work hardened surface left by the previous cut. Speeds and feeds, which must be positive at all times, are usually smaller than with more conventional metals. For turning operations, speeds can vary from 25 to 200 sfm. and feeds may range from 0.005 to 0.020 in.

While turning and facing are the easiest, drilling is the most difficult of the machining operations. In drilling, the major problem is that the chisel point of the drill work hardens the metal as it rubs constantly against the bottom of the

HANDY ALLOY DATA SHEET

HANDY & HARMAN ENGINEERING DEPARTMENT
82 FULTON STREET, NEW YORK 38, N.Y.

TEC and TEC-Z

...How to choose between a soft solder and a brazing alloy

Handy & Harman provides *two* alloys that fit between "something stronger than the average soft solder but not as strong as a silver-brazing alloy." They are named TEC and TEC-Z and their flow points are intermediate between soft solders and silver-brazing alloys. Joints made by these alloys are strong in straight tension or shear. For instance, butt joints of cold-worked copper can be made having a tensile strength of about 25,000 psi. This is approximately 10,000 psi. more than can be obtained with tin-lead soft solders. TEC joints retain their strength at elevated temperatures much better than the tin-lead soft solders. As shown in the table below, the strength of the solder itself at 425° F is about the same as a 50% tin–50% lead solder at room temperature in short-time tensile tests.

Applications—One example is a thermostatic bellows where the operating temperature is too high for soft solders (tin-lead), yet requires a joining medium which will not anneal the bellows. Another use is gun parts which require joint strength at higher than soft-solder operating temperatures *plus* corrosion resistance to solutions used in cleaning and blackening. Also for lamp bulb bases operating at approximately 350°-500° F. Automotive applications and heat exchangers. TEC conforms to Government Specifications Mil-S-19234 (Nord); both TEC and TEC-Z are available in sheet, wire, powder, and preforms to specifications.

NOMINAL COMPOSITIONS

	TEC	TEC-Z
Silver	5% plus or minus 0.5%	5% plus or minus 0.5%
Zinc		16.6% plus or minus 0.5%
Cadmium	95% plus or minus 0.5%	78.4% plus or minus 0.5%

PHYSICAL PROPERTIES

	TEC	TEC-Z
Color	White	White
Melting Point	640° F	480° F
Flow Point	740° F	600° F
Density (Troy oz/cu in.)	4.60	4.53
Electrical Conductivity (Cu=100)	22.0%	20.6%
Electrical Resistivity (Microhm-cm)	7.9	8.4

STRENGTH COMPARISON TEC vs. Pb-SN

	TENSILE STRENGTH LBS/SQ IN. TEC	TENSILE STRENGTH LBS/SQ IN. Pb-SN
ROOM	16,400	2,500
300° F	4,400	650
425° F	2,600	Melts
500° F	1,700	

The information and data on this page are available in our Handy Alloy Data Sheet. Ask for "TEC." Handy & Harman, 82 Fulton Street, N.Y.C. 38.

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Circle 1178 on Page 48-B

Machining . . .

hole. It is essential, therefore, that the drill never be allowed to rotate in the hole with the feed disengaged. Unless this precaution is followed, the bottom of the hole may be work hardened to such a degree that the metal can no longer be drilled.

The last tip is probably the most important of those listed – have patience, don't expect miracles – at least not immediately. There is no question that the high-temperature alloys are very special and peculiar materials. However, by exercising patience, perseverance and using the knowledge that has been developed, most of them can be machined with reasonably acceptable results.

Unusual Methods for Machining

The preceding comments apply, of course, to the conventional machining operations (turning, milling, drilling, tapping, and the like). Recent unorthodox approaches to these operations offer some promise for better machinability and higher production. One of these is subzero machining, in which, as the name implies, the conventional operations are performed at very low temperatures. The reasoning? This is simply a direct method of reducing temperature at the tool-work interface (which can approach 2000° F. in some instances). As for methods, deep freezing of the part itself is not as effective as flooding the area being cut with a dry-iced coolant, or surrounding the work area with CO_2 mist. The greatest benefits have been noted in turning, but improved milling and drilling have been obtained with certain grades. Though all tests have not been successful, the method justifies further study and experimentation.

In a directly opposite approach, hot machining has also been tried. In theory, this will reduce the shear strength of the work material so that more plastic flow occurs to alter the chip formation. Temperatures up to 1200° F. have been used. Here, as in subzero machining, the greatest benefits are noted in turning and milling, with little or no improvement in drilling.

Grinding, mentioned earlier, should not be overlooked as a method for shaping the hard alloys. One

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③ Duomelt®, Consumable Electrode Vacuum Melting

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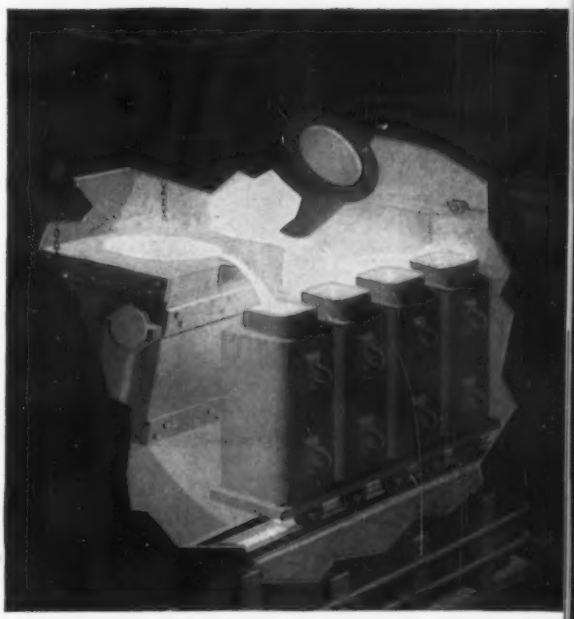
①



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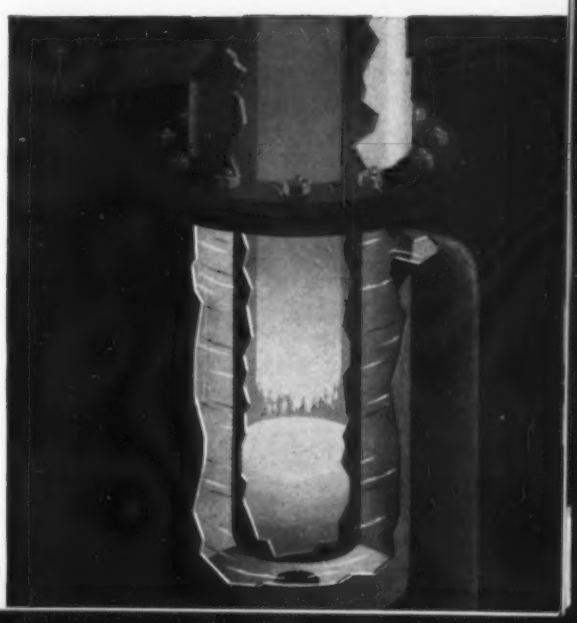

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Circle 1180 on Page 48-B

Machining . . .

application where grinding is popular is in the fabrication of jet-engine turbine buckets. The air foil section is usually precision forged to close tolerances, and then finished with a grinding or polishing operation. Many of the fastener designs in the root of the bucket, such as "Christmas tree" serrations, are formed by grinding.

Other methods of metal removal include chemical milling, spark arc disintegration and electrolytic machining. In chemical milling, acid baths remove metal from large surfaces. This method can be used on such sections with a minimum of distortion or warpage. Although penetration is slow compared with that of conventional machining, the simultaneous attack over a large surface may make metal removal rates quite favorable.

The spark-arc processes, including Elox and Method X, use a shaped electrode and an electrical discharge to "erode" a shape in very hard or difficult-to-machine materials. Recent improvements in control equipment have improved the rate of metal removal; however, there are still other limitations which restrict its application for all types of materials.

Electrolytic machining differs from electrical discharge methods in that metal is removed by electrochemical attack rather than by sparking or arcing. The metal removed goes into solution, forming metallic salts (as it does in chemical milling). When performed in conjunction with a grinding operation, the coolant also serves as the electrolyte, conveying current between the workpiece and the metal-bonded wheel. This principle has also been used with shaped electrodes to sink holes of irregular shape in various toolsteels and superalloys.

To sum up, the space-age metals present a real challenge to the machining specialist. However, the picture is certainly optimistic. After all, materials considered impossible to machine a few years ago are now being processed in everyday production, and problems that may seem without solution today will surely be solved tomorrow through perseverance and ingenuity.

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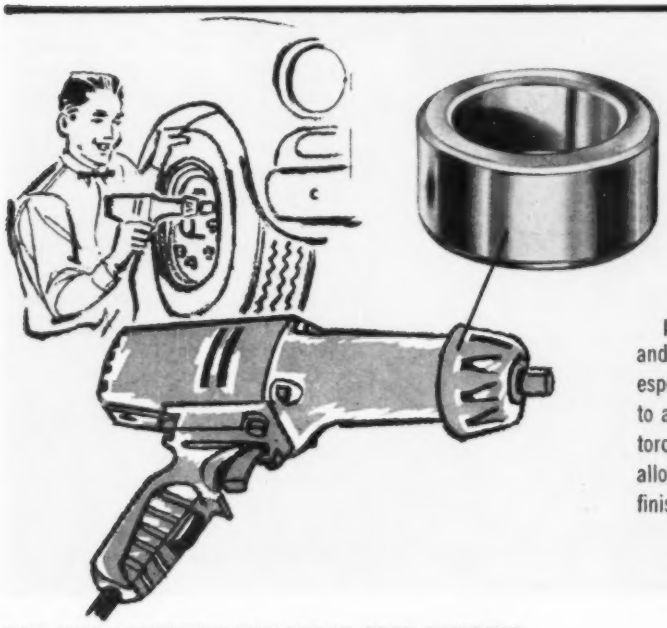

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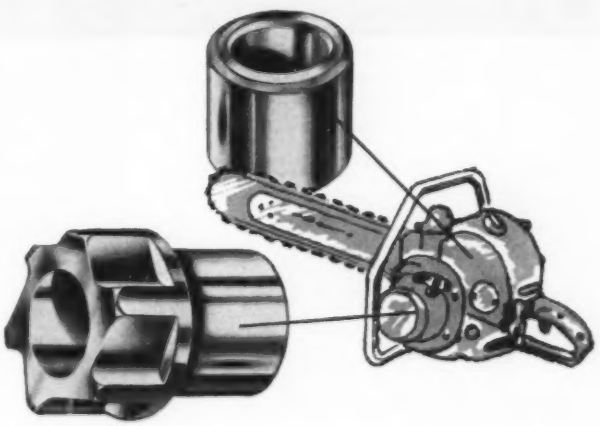

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326

Dry-Hydrogen Brazing...

(Continued from p. 96)

value if ideal brazing conditions cannot be maintained.

Preparing the Joint

The preparation of the joint is frequently taken too lightly. Parts that are assembled without removing dirt, oil, carbon, sulphur or lead compounds, draw or spinning compounds, paint, pencil or dye markings, or oxides in the joints cannot be brazed successfully.

Cleaning – Thorough cleaning is most important. Cleaning by degreasing in a properly maintained vapor degreaser will remove oil, but frequently other cleaning methods are necessary. Washing and rinsing can be used for some applications. Cleaning with acetone is frequently employed after prior cleaning.

For stainless steel, pickling to remove the resulting sooty deposit is sometimes carried out to promote wetting by the brazing alloy. This is not necessary if the hydrogen atmosphere is sufficiently dry and the temperature is high enough to remove the light residual, nonapparent oxide which forms on stainless steel at room temperature over a period of time.

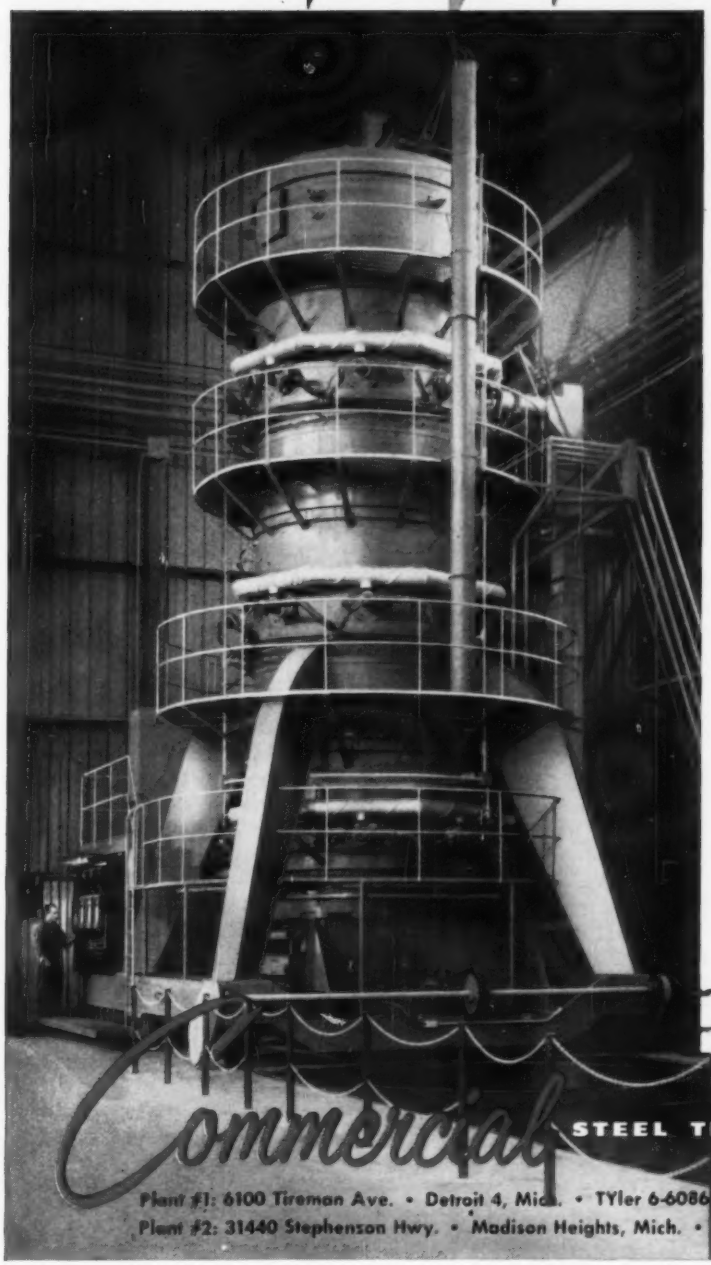
If the removal of these oxides is important, as when brazing at a relatively low temperature, pre-firing in very dry hydrogen at a higher temperature before assembly is an excellent first step. For the "problem" metals containing aluminum or titanium in appreciable percentages, special preparation is required. Metals containing these alloys can be brazed without flux in dry hydrogen if the joint areas are nickel plated before assembly.

Applying the Brazing Alloy

Application of the brazing alloy involves not only the selection of the form of the alloy, but also where to put it, how to apply it, the quantity to use, and where to mask the part to prevent flow to undesired areas.

Whenever possible the alloy should be located so that its flow into the joint will be aided by gravity; however, if the alloy can be kept close enough to a joint for capillary action to start, it will pull uphill into a joint. Grooves within

a giant step . . . FORWARD!



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Dry-Hydrogen Brazing...

a joint act as excellent aids in placing an alloy prior to assembly. Shims of brazing alloy are satisfactory within a joint only when movement can take place to close the gap when the alloy flows.

Powder Alloy – The methods of applying wire and shim material are fairly obvious, but special techniques are required when powder is used. It may be applied dry, in some instances, and then locked in place by wetting it with an acrylic cement. Or it may be mixed with acrylic to form a slurry and then applied through a small tube. For flat surfaces, it may be sprayed on with a metalizing gun.

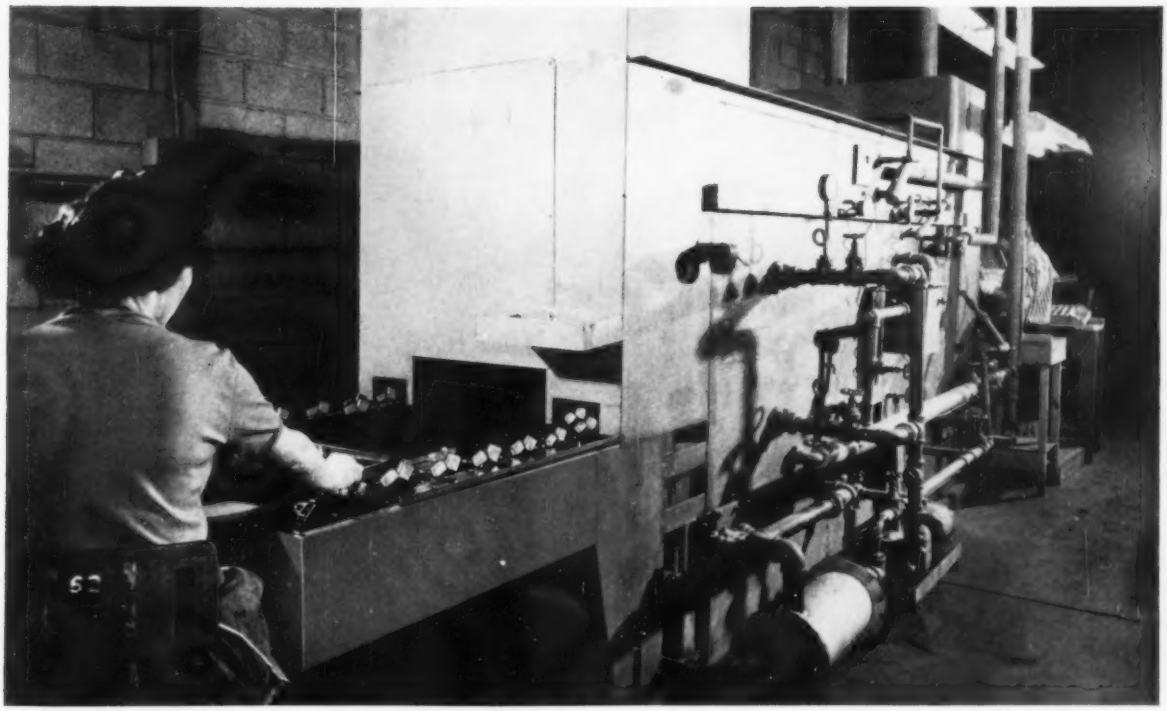
Match Load and Furnace Size

Actual loading in the furnace requires careful attention. Retort size should be selected to match the load of parts for uniform heating and to permit supports for the assemblies to be made as simple as possible. The fewer supports and fixtures used the better. If graphite supports are used, consideration must be given to possible contamination from oxides and entrapped air and moisture and from carbon transferred to the assembly.

Expansion – The expansion of the support and fixtures must match that of the assembly if any difference will change their relative positions. This involves the coefficients of expansion of the assembly components, fixtures and supports as well as the differential expansion and contraction that may occur during the heating and cooling cycles. Possible warpage of the fixtures and support must also be given careful attention.

When supports and fixtures are to be used, consideration must be given to the possibility of their being brazed to the assembly. Careful masking is required if any point or area of contact is near a braze or can be reached by the brazing alloy.

Success of the brazing cycle depends, of course, on controlling the temperature and purity of the hydrogen. Next month the second part of this article will give some hints on temperature regulation and how to minimize contamination, along with a check list which itemizes the factors that affect brazing results.



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When baths are cleaned out, Zippo gets full recovery of the solvent, and it is fully stabilized so they never have the cost and trouble of adding fresh stabilizer to maintain bath strength.

Zippo likes the several different degreasing jobs that Nialk TRICHLOR does. As many as five different metals might be degreased in a day—brass, stainless steel, die-cast zinc, copper and gold.

Even considering all the use Zippo gets from each bath, they have never had to sacrifice quality. There has never been a need to titrate or run any other type of test.

Nialk TRICHLOR can bring you the same benefits and cost savings. Hooker technical experts can help you to set up your degreasing operations, then check regularly to make sure your operation remains trouble-free. Zippo obtains Nialk TRICHLOR through Ken C. Merrill Co.

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Circle 1186 on Page 48-B

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Proven performance superiority has induced many tool and hardware manufacturers to switch to Malleable castings so they, too, can guarantee their products. At the same time, they often reduce their costs. How? Because Malleable provides more strength per dollar than any other metal; Malleable is the most machinable of all ferrous metals of similar properties; Malleable is truly outstanding for its toughness, ductility, castability and corrosion resistance. While Malleable's natural appearance is attractive, a wide variety of finishes can be applied for added customer appeal.

Improve your products by using Malleable castings. Check with any Malleable producer that displays this symbol —

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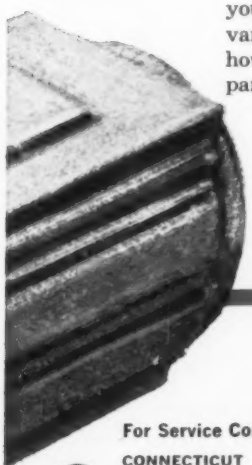
The manufacturer of this unit converted his entire line of machinist vises to Malleable... then guaranteed them against breakage. Not one claim has been made in three years!

$10,000 per year are saved by the manufacturer of this hydraulic jack since he converted the 16 inch long caster bar to a Malleable casting. The bar originally was a fabricated part that required shearing, punching, sawing, chipping, grinding and reaming, plus welding at eight points. The Malleable casting is delivered ready-to-use at a savings of $2.68 per unit.

The wide range of Malleable's properties permits its use in hundreds of tool and hardware applications. Besides the examples shown here, Malleable is used for load binders, chain hoists, hinges, many kinds of clamps, pliers, trailer hitches, jack screws, gun frames, fence fittings, casters, brackets and pipe threading and cutting tools.

When you're interested in high quality and long life, Malleable gives your products many competitive advantages. We'll be glad to show you how. Write or call one of the companies listed below.



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PERSONAL MENTION

RALPH A. SCHAEFER has been appointed director of research at the Carl F. Norberg Research Center of the Electric Storage Battery Co. in Yardley, Pa.

A 1935 graduate in chemistry from Western Reserve University, he received his master's degree in physical chemistry a year later and his doctor's degree in 1941. His experience in industry includes 22 years' work in divisions of the Clevite Corp., starting in 1936 when he joined Cleveland Graphite Bronze Co. He rose from research chemist to supervisor of chemical development, director of research and then technical advisor to the president. He was also vice-president of the Clevite Brush Development Co. division for two years. He left Clevite in 1958 to become director of engineering and research at Bunting Brass and Bronze Co.

He belongs to many technical groups and is particularly active in the Electrochemical Society. He is president for 1960-61, and in the past has served as vice-president, national director and director of the Cleveland Section. He is also a past president of the American Electroplaters' Society (1954-55).

David W. Lillie – now manager of the materials application and evaluation section of the General Electric Research Laboratory in Schenectady, N.Y.

Ray J. Van Thyne – from supervisor of reactor metallurgy to an assistant director of metals research at the Armour Research Foundation of Illinois Institute of Technology.

G. Letendre, Université Laval, Quebec, Que. – elected president of the Province of Quebec Chamber of Commerce.

Walter L. Keene – from director of research and metallurgy to general manager of operations, Superior Steel Div. of Copperweld Steel Co., Cargnegie, Pa.

John B. Newkirk – from research associate in the metallurgy and ceramics department, General Electric Research Laboratory, Schenectady, N.Y., to professor of chemical and metallurgical engineering at Cornell.

Robert A. Eidam – appointed general superintendent of the East Chicago (Ind.) Works of Blaw Knox Co.'s foundry and mill machinery division.

Kenneth D. Hunt – now assistant district manager of the Michigan district of Braeburn Alloy Steel Corp., Braeburn, Pa.

F. P. A. Robinson – awarded a Ph.D. degree in December by the University of the Witwatersrand, Johannesburg, South Africa.

Arthur J. Abrams – from plant metallurgist in Bridgeport, Conn., to assistant plant manager in Chicago for Handy & Harman, New York.

F. W. C. Boswell – from head, metal physics section, Department of Mines and Technical Surveys, Ottawa, Ont., to associate professor in the department of physics, University of Waterloo (Ont.).

Hiland G. Batcheller, chairman of the board of Allegheny Ludlum Steel Corp. – named chairman for the Capital City Region of New York State for the Science Center Fund of Rensselaer Polytechnic Institute. The fund seeks a total of $8,300,000 for the four buildings comprising the center. Two of the buildings under construction, at the Troy, N.Y., campus are scheduled for completion in May.

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Circle 1142 on Page 48-B

Personals . . .

Charles H. Moore – from executive director of corporate research and development and manager of semiconductor operations for P. R. Mallory and Co., Inc., to technical director of the Copper Products Development Assoc., Inc., New York.

Thaddeus Giszczak – from chief metallurgist of the General Motors Central Foundry Div.'s Defiance, Ohio, plant, to divisional chief metallurgist, at divisional headquarters in Saginaw, Mich.

Lawrence L. Garber, vice-president, Electric Autolite Co., Toledo, Ohio – named group executive, directing the operations of three company divisions.

Robert F. Casler – from Bridgeport Brass Co., to process metallurgist with Brush Beryllium Corp., Elmore, Ohio.

Andrew F. Grimm – from metallurgist-statistician, Republic Steel Corp., Buffalo, N.Y., to quality control engineer, Cramer Controls Corp., Centerbrook, Conn.

Richard R. Hartwell – now assistant to the general manager, technical service division, Canco Div., American Can Co.

Allen D. Zumbrunnen – now an assistant metallurgical engineer, metallurgy division, Argonne National Laboratory, Argonne, Ill.

L. W. Kunkler – from assistant manager, engineering services, Cleveland district of Air Reduction Sales Co., New York, to district manager of the Buffalo office.

Carl F. Joseph – retired as technical director of the Central Foundry Div. of General Motors Corp., Saginaw, Mich., after 43 years with G.M.

Walter E. Littmann – from section chief to chief research metallurgist, Timken Roller Bearing Co., Canton, Ohio, succeeding **Arthur L. Christenson**, now assistant to the general manager, steel and tube operations. **Chester F. Jatczak**, a research metallurgist, holds Dr. Littmann's former position as section chief in physical metallurgical research.

How the choice of a cutting fluid affects your costs

Often—perhaps *too* often—the supplier of cutting fluids for machining or grinding, points to the quality of the work and totally ignores its surprising counterpart—a lower over-all cost of operation.

Many a user of petroleum-base fluid might never notice the oversight. A better fortified coolant, which costs more per gallon, would not seem to reduce the final cost of the work, although it can readily be proven to produce better machined parts.

But it is pertinent to examine more closely the cost factors. The facts may surprise machine shop men who have not fully considered all the items which influence their costs. The measurable, tangible cost factors are these:

- Initial cost
- Cost of mixing
- Production rates
- Tool or wheel life
- Machining cost
- Overhead
- Cost of cleaning
- Life of the fluid
- Cost of rejects
- Reworking costs caused by rust

A comparison of first cost with final cost per piece, made on the basis of long experience with both conventional water-soluble oils and the newer chemically conceived fluids reveals some astonishing figures. Just a quick glimpse:

- The modern fluid costs about four times as much as the old soluble oil.
- But that modern coolant can be cut with three times as much water as the oil-base fluid.
- The modern coolant requires less make-up.
- It lasts over six times as long as the oil emulsion—contains nothing to make it turn rancid.
- It enables faster production—machines can be speeded up.
- It requires less frequent emptying and cleaning of machines.
- The over-all cost of coolant per piece produced has repeatedly proved to be upwards of *40% less* with a good chemically conceived coolant than with a conventional soluble oil!

There are intangibles, too, which are not as measurable, but which affect both cost and quality. To mention a few: Cleanliness of shop, operator satisfaction, visibility of work, smoke problems, accuracy of work, adaptability to a wide range of jobs, and safety (fire hazard, slipperiness of floors, etc.).

It is illuminating to examine all of these direct and indirect influences a cutting fluid can exert. Little wonder that it is termed the "third leg" of the base on which successful machining depends—the others, of course, being the tooling and efficiency of the machine itself.

Our concern is with the fluid itself, because Houghton has made and supplied many types through the past half-century.

Our recent successes have been with the chemically conceived types of coolants, scientifically fortified to do a double job of improving quality *and* cutting final costs. *Hocut 237* is a perfect example of such a coolant. Data on its applications and availability will gladly be supplied. E. F. Houghton & Co., 303 W. Lehigh Ave., Philadelphia 33, Pa.

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INDUSTRY'S PARTNER IN PRODUCTION

Circle 1144 on Page 48-B

Personals . . .

Jerome B. Cohen, assistant professor, department of materials science, Northwestern University – received the Robert Lansing Hardy Award of the Metallurgical Society of A.I.M.E., awarded in recognition of a metallurgist, under the age of 30, who shows exceptional promise.

Harry P. Croft – now vice-president, research, for the Copper Range Co., Boston.

Henry E. Frankel – from the National Bureau of Standards to the staff of the satellite applications systems division of the National Aeronautics and Space Administration at the Goddard Space Flight Center in Greenbelt, Md.

Gail B. Hamilton, Jr. – from manager, marketing development and research for the industrial heating department, General Electric Co., Shelbyville, Ind., to manager of process automation sales at G.E.'s industry control department in Salem, Va.

William G. Pfann, metal research specialist, Bell Telephone Laboratories – received the 1960 Professional Progress Award of the American Institute of Chemical Engineers recognizing "outstanding progress in the field of chemical engineering".

Niranjan M. Parikh – now a senior metallurgist in the metals research division of Armour Research Foundation of Illinois Institute of Technology.

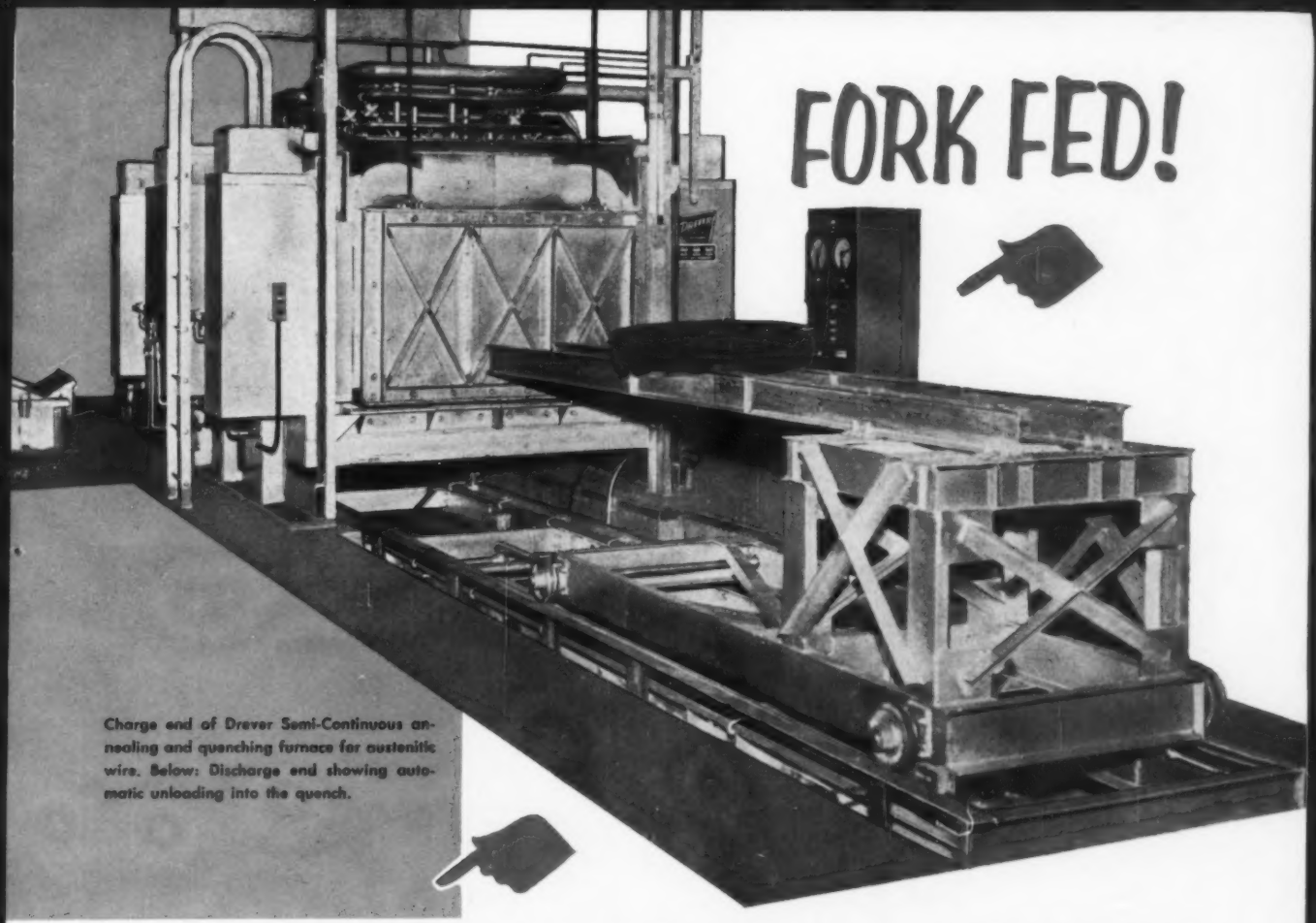
Louis O. Schaefer – now works manager of the steel fabricating division of the Austin Co., Cleveland.

Joseph G. Wortley – from general manager of the Kenilworth (N.J.) plant of Jones & Laughlin Steel Corp.'s Stainless and Strip Div., to president of the Penn-Harris Steel Co., Harrisburg, Pa.

William A. Singer, chairman of the board of Apex Smelting Co., Chicago – received the Second Annual Phoenix Award of the Philadelphia Metals Assoc.

Harry Schwartzbart – from supervisor of welding research to an assistant director of metals research at Armour Research Foundation of Illinois Institute of Technology.

FORK FED!



Charge end of Drever Semi-Continuous annealing and quenching furnace for austenitic wire. Below: Discharge end showing automatic unloading into the quench.

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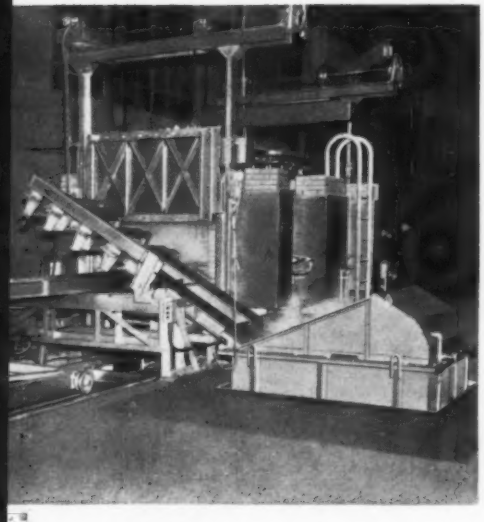

A push of a button after the operator has placed the coil on the charging fork sets off the complete automatic operation of this Drever Furnace handling austenitic stainless steel wire in coils. It is Drever engineered to process coils through both furnace and quench on the basis of a short heating cycle and minimum scale build up.

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Circle 1146 on Page 48-S

Metals Engineering Digest

. . . Interpretative Reports of World-Wide Developments

Aging Refractory Metals

Digest of "Strain Aging of Refractory Metals", by A. C. Imgram, DMIC Report 134, Aug. 12, 1960, Defense Metals Information Center, Battelle Memorial Institute.

TODAY, PRIMARY INTEREST in refractory metals is in high-temperature structural applications such as jet, rocket, or nuclear engines, as well as in space vehicles and missiles. Although major research emphasis has been directed toward difficulties in fabrication, low-temperature brittleness and high-temperature oxidation, it can be assumed that since most refractory metals have a body-centered cubic crystal structure, the phenomena of strain aging will also affect their mechanical properties in a manner similar to the way it affects the mechanical properties of steel. It is therefore of interest to examine the strain aging behavior of this class of metals. In this report, the author reviews the data of various investigators, giving descriptions of testing conditions and experimental techniques where they are of specific interest or have a significant bearing on the results.

The refractory metals considered and their respective crystal structures are listed below:

Group V-A	Group VI-A
V – bcc	Cr – bcc
Cb – bcc	Mo – bcc
Ta – bcc	W – bcc

Group VIII-A
Platinum-Group Metals

Ru – hcp	Os – hcp
Rh – fcc	Ir – fcc
Pd – fcc	Pt – fcc

A discussion of the theory of strain aging (based largely on the dislocation models proposed by Cottrell) is presented to establish a base for the interpretation of strain aging phenomena in selected metals. Cottrell has pictured the strain aging phenomena in body-centered cubic metals as a result of diffusion of interstitial solute atoms to positions of lowest energy in the stress field of dislocations. A segregation of interstitial solute atoms at dislocation lines (Cottrell atmosphere) restricts their movement and is the cause of yield point discontinuities. In strained specimens, the return of the yield point is associated with the diffusion of interstitial solute atoms back to the dislocation line after the specimen has yielded and the dislocations have been pulled free of their locking atmospheres. Maximum points in strength-temperature curves and serrated stress-strain curves are attributed to the continuous diffusion of interstitial solute atoms to the vicinity of moving dislocations as a specimen is being strained. It is thought that substitutional solute atoms are responsible for the strain aging behavior of face-centered cubic and hexagonal close-packed metals.

Review of Experimental Studies

Representative examples of the numerous experimental works cited in this paper, and the interpretations offered by the author, are presented for each of the three groups of the refractory metals. The body-centered cubic refractory metals of Group V-A all have ductile-to-brittle transition temperatures below room temperature and are relatively sensitive to strain aging. Thus, in one investigation Pugh investigated the behavior of powder metallurgy tantalum sheets between 195 and 1200° C. (385 and 2190° F.). The material was annealed in vacuum to produce a recrystallized grain size of A.S.T.M. 6 to 7. Interstitial content was 0.0056% oxygen, 0.01% nitrogen, and 0.02% carbon. Minimum points were detected in the

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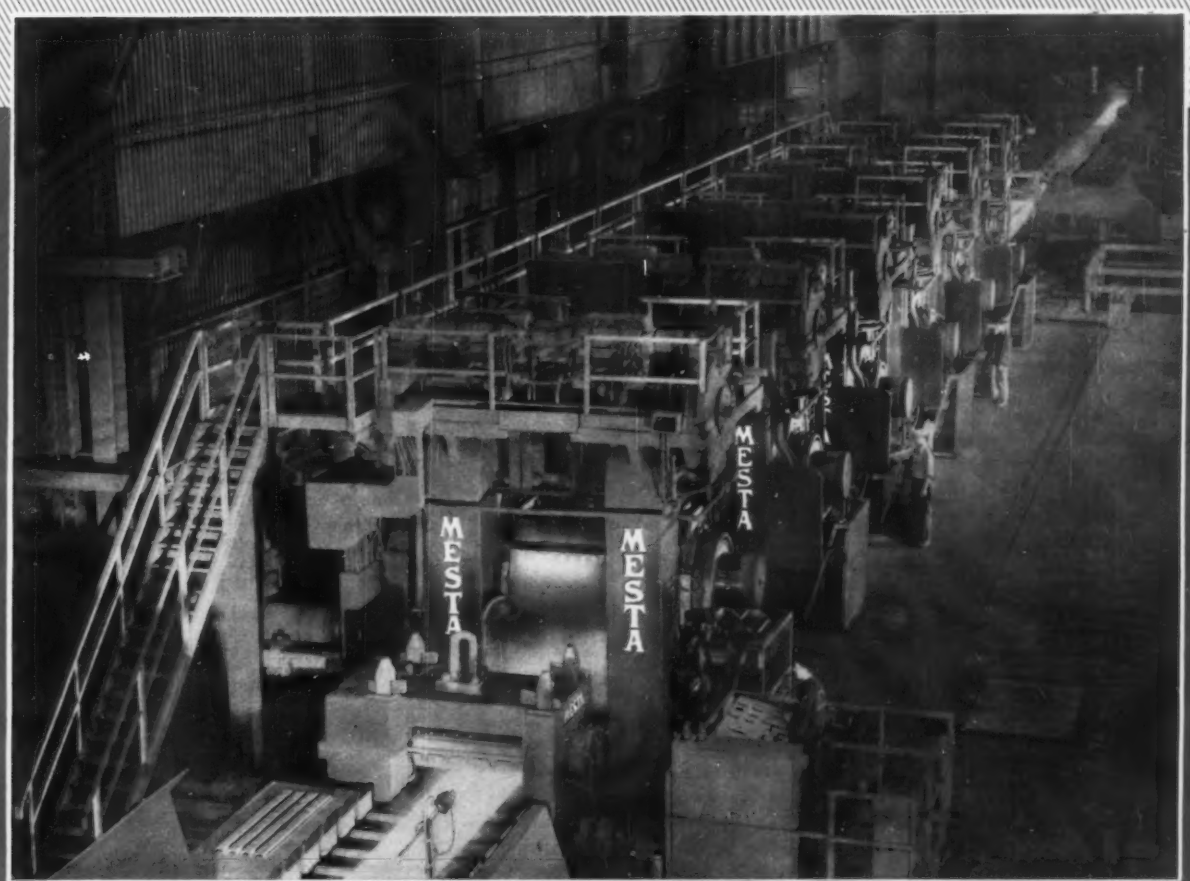

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Circle 1147 on Page 48-B

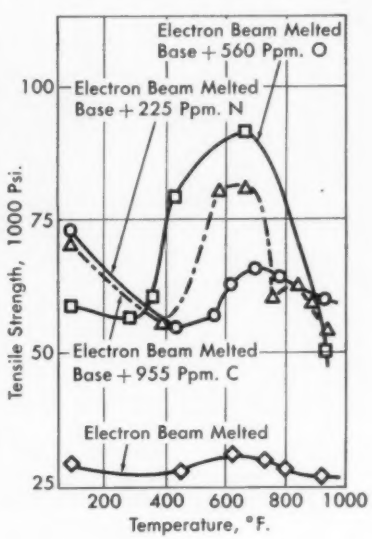
Refractory Metals . . .

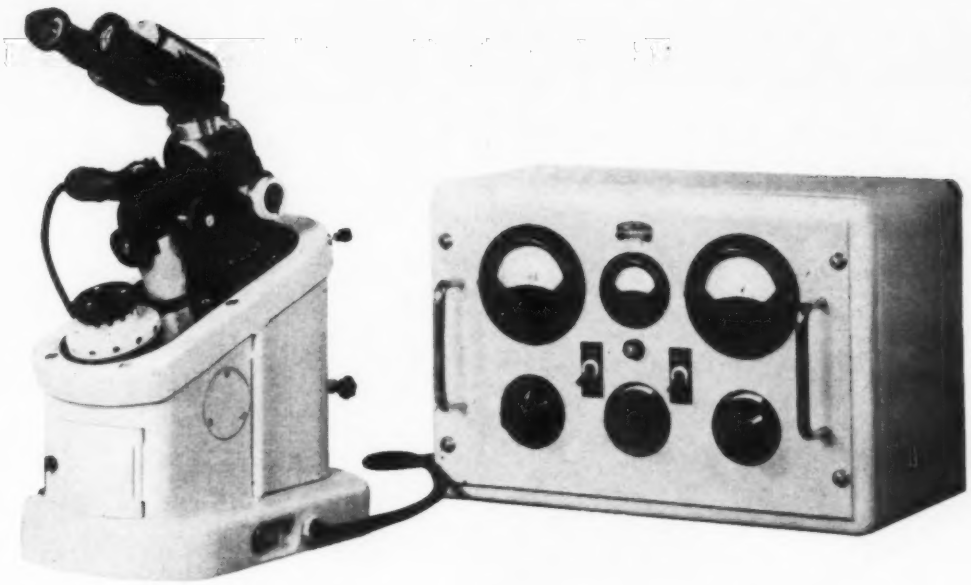
strain rate and elongation-temperature curves at 200 and 600° C. (390 and 1110° F.). This closely corresponds to the temperatures at which maximum points were observed in the curve of strain hardening exponent against temperature. Maximum points were detected in the curve for both yield strength and ultimate tensile strength against temperature at approximately 300° C. (570° F.). An indication of another maximum point in both strength curves suggests that two different interstitial atomic species are producing strain aging effects.

This investigation also included return of yield point tests. Initially, the specimen was loaded to about 0.04 strain at −73° C. (−95° F.) and was then unloaded. Immediate reloading at the same temperature resulted in a smooth continuation of the flow curve. Reloading after aging at 227° C. (445° F.) for 10 min. resulted in the reappearance of the yield point and a slightly higher flow stress. The slightly higher flow stress was attributed to strain aging. Insufficient data were available to calculate the activation energy of strain aging.

In another investigation, researchers studied the effects of interstitial carbon, nitrogen and oxygen on high-purity (60 ppm. total interstitial content) electron beam melted tantalum by separately adding 560

Fig. 1 — Tensile Strengths of Tantalum With Various Grades of Purity





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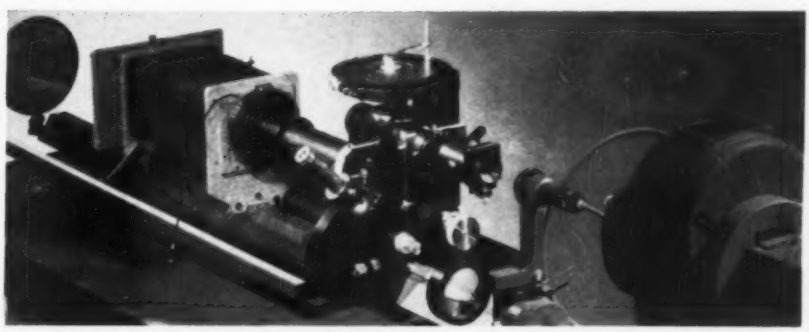

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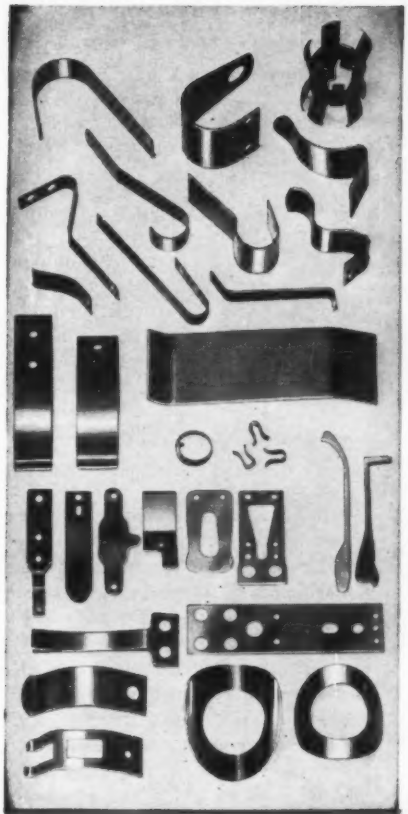
Circle 1149 on Page 48-B

Refractory Metals . . .

ppm. oxygen, 955 ppm. carbon, and 225 ppm. nitrogen to three different heats of the high purity stock. Flat tensile specimens, prepared with a 0.035 and 0.250 in. reduced section, were tested at various temperatures covering the ranges between 25 and 600° C. (77 and 1110° F.). The results of these experiments are summarized in Fig. 1. Serrated stress-strain curves were observed with the tantalum-nitrogen alloy in all tests conducted above 225° C. (435° F.). The most pronounced effect was at 300 and 330° C. (570 and 625° F.). With the tantalum-oxygen alloy, serrations were noted at 135 and 245° C. (275 and 475° F.). Serrations were obtained for the tantalum-carbon alloy at all testing temperatures except 25 and 338° C. (77 and 640° F.). The relation proposed by Cottrell predicting the point at which pronounced serration will occur was used to calculate the minimum temperatures at which serrated stress-strain curves should be observed due to each interstitial solute. The calculated temperatures were 304° C. (580° F.) for oxygen, 474° C. (888° F.) for carbon and 582° C. (1075° F.) for hydrogen. Therefore, the observed strength peaks in the vicinity of 300° C. (570° F.) were attributed to interstitial oxygen, while the strength peak at approximately 450° C. (840° F.) in the tantalum-carbon alloy was attributed to interstitial carbon. It was predicted that at higher testing temperatures a strength peak due to nitrogen would appear.

The body-centered cubic refractory metals in Group VI-A are less affected by strain aging than are those in Group V-A, and they have ductile-to-brittle transition temperatures above room temperatures. Pugh has investigated the tensile properties of as-swaged and recrystallized arc melted molybdenum from 29° C. (84° F.) to over 1100° C. (2010° F.). Recrystallized specimens annealed at 1000° C. (1830° F.) for 4 hr. developed a recrystillized grain size of 500 grains per sq.mm. Interstitial content was 0.0003% oxygen, 0.003% hydrogen, 0.001% nitrogen, and 0.05% carbon. Tensile specimens were tested at a strain rate of 0.2 in. per in. per



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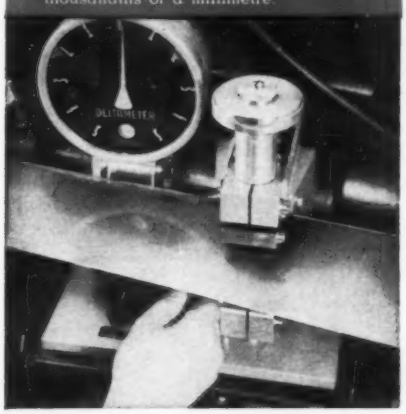

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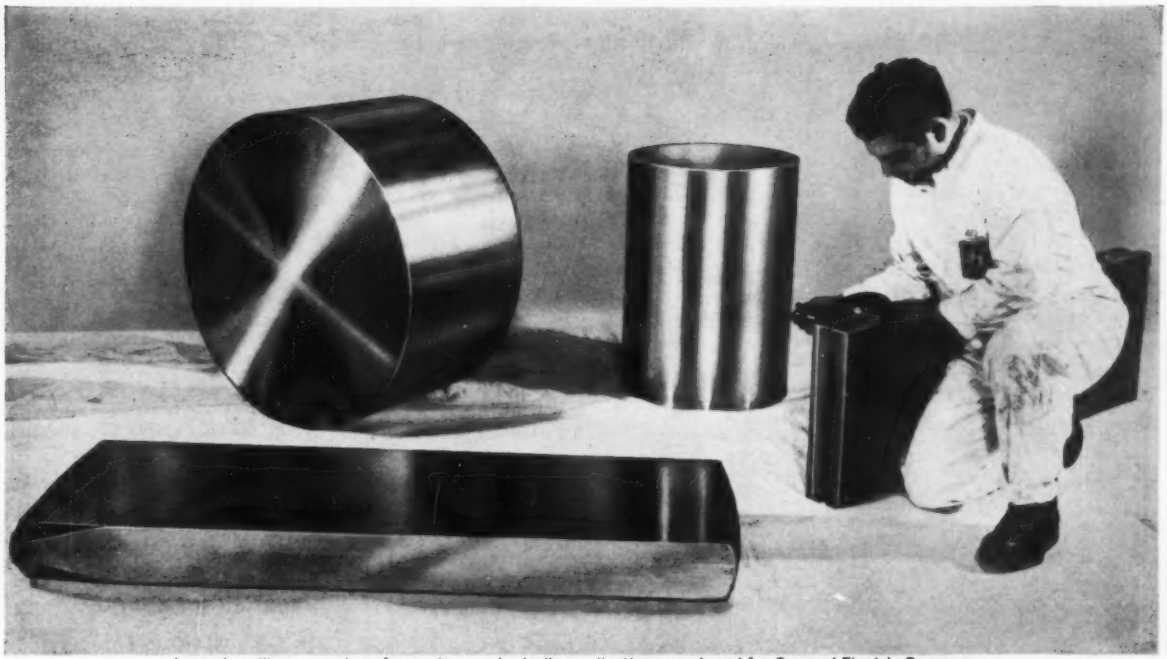
Circle 1151 on Page 48-B

Refractory Metals . . .

min. All tests with the exception of those at room temperature were conducted in vacuum. For the as-swaged material, maximum points were detected in the yield strength, ultimate tensile strength, and strain hardening exponent curves at about 730° C. (1345° F.). A minimum point was also observed in the strain rate sensitivity curve at approximately 550° C. (1020° F.). These data indicate that strain aging occurred between about 550 and 900° C. (1020 and 1650° F.). In the recrystallized material, the temperature dependence of these properties was similar but varied in magnitude. Maximum and minimum points were not as distinct as those observed for the as-swaged specimens. Thus the likelihood of strain aging between 300 and 800° C. (570 and 1470° F.) is indicated.

The strain aging behavior of the platinum group metals (ruthenium, rhodium, palladium, osmium, iridium and platinum) were considered together, although rhodium, palladium, iridium, and platinum have a face-centered cubic crystal structure, and ruthenium and osmium have a hexagonal close-packed crystal structure. Although the high-temperature behavior of these metals is similar to that of the body-centered cubic refractory metals, it seems improbable that interstitial solute atoms can interact with the shear field of screw dislocations in face-centered cubic or hexagonal close-packed crystals. Regardless of the true nature of dislocations in close-packed crystals, it is thought that only substitutional solute atoms can interact with them. This suggests that yield point and strain aging effects in face-centered cubic and hexagonal close-packed crystals are associated with the diffusion of substitutional solute atoms to positions of lowest energy in the stress field of dislocations where they can retard the movement of dislocations under applied stress.

Holden and others have determined the temperature dependence of the tensile properties of annealed ruthenium, rhodium, palladium, iridium and platinum. Tensile specimens (representing each material at several purity levels) were tested at a strain rate of 0.0075 in. per in. per



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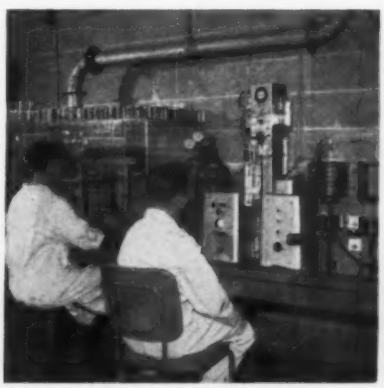

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Circle 1153 on Page 48-B

Refractory Metals . . .

min. Peaks in the strength-temperature curves, indicating the likelihood of strain aging, were detected at about 300° C. (570° F.) for rhodium, 250° C. (480° F.) for palladium, 500° C. (930° F.) for iridium, and 250° C. (480° F.) for platinum. Data for the temperature dependence of tensile properties of osmium are not yet available. The substitutional atoms responsible for this behavior are not known.

In other research, peaks have been noted in the hardness-annealing temperature curves of platinum, palladium and rhodium at a temperature slightly below that at which crystallization begins. This may be due to the thermally induced migration of solute atoms back to the stress fields of dislocations which can cause an increase in yield strength and consequently in hardness. Therefore, these peaks may be considered an indication of strain aging.

Strain aging has been discussed in terms of strain-induced diffusion of solute atoms to positions of lowest energy in the stress fields of dislocations. The interaction of solute atoms with dislocations then restricts the movements of the dislocations resulting in the appearance of a yield point and other strain aging effects. It is thought that interstitial solute atoms are responsible for the strain aging behavior of body-centered cubic metals while substitutional solute atoms are responsible for strain aging behavior in the face-centered cubic and hexagonal close-packed metals. Indications of strain aging are:

1. Return of yield point in strained tensile specimens.
2. Serrated stress-strain curves.
3. Maximum points in strength and strain hardening exponent versus temperature curves.
4. Minimum points in ductility, and rate sensitivity versus temperature curves.
5. Stepped creep curves.

Care must be taken not to confuse strain aging with other aging or precipitation mechanisms. Compound formation or any other purely precipitation mechanism will often result in similar effects.

In many situations, there are not enough data available to provide a rigorous comparison with proposed theory. However, good correlation in several instances, together with excellent agreement found between theory and experimental observations in iron and steel, leads to the acceptance of the dislocation models for strain aging proposed by Cottrell.

A bibliography of 47 references is included. W. W. Austin

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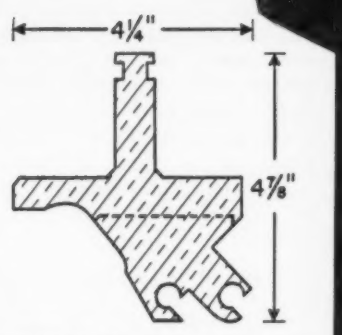

DOTTED LINE SHOWS where two copper extrusions were brazed together to make original part. When you consider the intricate shape and the weight of the part (a 3⅞" section measuring 4¼" x 4⅞", weighing 8 lbs. 7 ozs.), you can readily understand why it was at first thought impractical to make it into a single extrusion.

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Circle 1231 on Page 48-E

Corrosion by Antifreeze

Digest of "The Corrosion of Road Vehicle Engines by Anti-Freeze Solutions", by H. H. Collins and R. I. Higgins, *Corrosion Prevention & Control*, February 1960, p. 36-45; March 1960, p. 41-48.

STUDIES IN ENGLAND on the corrosive behavior of antifreezes of the ethylene glycol type have been reported in a paper (British Cast Iron Research Report 510) which should interest many engineers. In this work, solutions containing triethanolamine phosphate and sodium mercaptobenzothiazole for rust inhibitors were evaluated because those compounds are the most widely encountered in commercial anti-freezes.

The study was prompted by observations that there were numerous instances of severe engine and water pump corrosion in heavy-duty trucks. Further, the problem seemed to arise during the first year of use. Investigation also showed that the corrosion problem predominated in trucks built during the winter months, in vehicles which had the antifreeze added at the factory. When severely corroded engines in this category were examined, more than 95% had experienced defective seals between the cylinder head and the block.

Based on three-month tests, the rate of corrosion on water pump impellers ranged between 0.20 and 0.40 in. per year. An interesting feature of the cast iron corrosion is that the iron dissolves away, leaving a skeletal graphite structure in the shape of the original specimen. Because of this graphite skeleton, rust precipitation capable of inhibiting further oxidation does not occur.

Used antifreeze solutions were extensively analyzed to determine the nature of corrosive ingredients which form under oxidizing conditions. The solutions were found to be acid, principally due to oxidation of the glycol to form glycollic and formic acids, formic acid predominating.

The experimenters built a test rig to duplicate engine conditions and conducted numerous experiments to determine the rate of inhibitor depletion and its effect on glycol oxidation. Results clearly

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- **The Effect of Prestraining and Retempering on AISI 4340. Stephenson, MIT. Cohen, Bethlehem Steel Co.**
- **Effects of Surface Condition on the Mechanical Properties of Beryllium Sheet. Matthews, Jacobson, Lockheed Aircraft Corp. Ward, International Nickel Co.**
- **Direct Reduction of Ferric Oxide by Solid Carbon in Vacuum. Yun, Argonne National Laboratory.**
- **Constitution Studies of the Indium-Rich Portion of the System Antimony-Bismuth-Indium. Peretti, U. of Notre Dame.**
- **Constitution and Transformation Behavior of the Ti-8A1-8Zr-1 (Ta-Cb) Alloy. Margolin, New York University. Ence, Republic Aviation Corp.**
- **Phase Equilibria in the Yttrium-Aluminum System. Lundin, Klodt, U. of Denver.**

THE DECEMBER ISSUE

As the *annual* ASM Transactions has done in the past, the December issue of the Transactions Quarterly will carry the ASM Annual Report; Discussions of papers presented at the National Metal Congress; Technical Notes; the Campbell Memorial Lecture. Transactions will continue to be available in annual bound volumes.

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Corrosion . . .

demonstrated that rapid oxidation occurs only after inhibitors are seriously depleted, and that a continuing source of oxygen must be available if corrosion is to occur. It was also observed that corrosion reactions are catalyzed by having brass in the circuit, apparently through dezincification and ion exchange routes. As much as 2000 ppm. of zinc were found in systems containing brass in the presence of the antifreeze solution.

The authors concluded that commercial antifreezes lose their inhibitors within about 2 months or 4000 miles of service, and that the principal agent causing corrosion thereafter is formic acid. Corrosion rates of antifreeze solutions are much higher than for water, suggesting that winterized cooling systems should be flushed and the antifreeze replaced with water as early as possible. J. L. WYATT

Properties of Beryllium Sheet

Digest of "Effects of Surface Condition on the Mechanical Properties of Beryllium Sheet", by W. V. Ward, M. I. Jacobson and C. O. Matthews, ASTM Preprint No. 249, 1961. Paper to be presented at the National Metal Congress, October 1961, Detroit.

BECAUSE OF ITS DESIRABLE PROPERTIES – low density, high strength-to-weight ratio and high modulus of elasticity – beryllium has a prominent place in the list of materials which can be used in airframes, missiles and space vehicles. At the same time, its low ductility and brittleness require particular care to make the most of what little ductility it does possess. Among suggested causes for brittleness of beryllium sheet are limited modes of deformation, orientation effects, surface defects and irregularities, and, perhaps, impurities.

This investigation was intended to determine the effects of surface conditions (obtained by different methods of finishing) on tensile properties over a range of temperature from subzero to elevated. To accomplish this, the researchers employed notched tensile tests, impact tests over a range of temperatures, and fatigue tests at room temperature. Surface conditions were further studied by surface roughness measurements, residual stress determinations and metallographic studies.

Rolled beryllium sheet was used in most of the studies. The surface preparations used included:

1. **As received** – As supplied by the manufacturer. This had the greatest variety of finishes of all the surfaces studied, containing many fine microcracks, 0.002 to 0.003 in. deep, normal to the plane of the sheet and transverse to the rolling direction.

2. **Etched** – Removal of 0.002 in. electrolytically from each surface (after about 0.003 in. had been removed from each surface by grinding with 600-grit cloth). This treatment appeared to remove all evidence of subsurface damage caused by various machining and finishing processes.

3. **Etched and scratched** – Electrolytically etched as above, followed by scribing both sides of the speci-

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MARCH, 1961

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For more information circle 1234 on page 48-B

* * *

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For more information circle 1235 on page 48-B

* * *

A WORLD-WIDE SEARCH -- The search never ends for high-grade ores, from which ferroalloys are made. Exploration teams of Union Carbide Ore Company search all parts of the world -- sometimes through tropical jungles, arid deserts, and unexplored rivers. Their goal: to discover new ore deposits to satisfy the growing demand for ferroalloys. Union Carbide's integrated mine-to-furnace operations assure a continuous supply of ferroalloys...when you want them. For the full story, write for the article, "From Earth to Hearth," in the Winter 1961 issue of UNION CARBIDE METALS REVIEW.

For more information circle 1236 on page 48-B

* * *

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For more information circle 1237 on page 48-B

* * *

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Beryllium Sheet . . .

men (to approximately 0.001 in.) transverse to the rolling direction.

4. **Ground** – Ground to a relatively smooth surface, with a high speed grinding wheel. This treatment produced a number of subsurface cracks and twins in the surface layers.

5. **Ground and peened** – Ground with abrasive wheel as above, followed by peening with SA-170 chilled iron shot.

6. **Milled** – Machined with end or horizontal cutters, cutting depth variable for roughing, and 0.002 in. of metal removed in finishing, without using lubricants. Milling also produced cracks and twins at the surface.

Specimens with etched surfaces were stronger and more ductile than specimens with the other surfaces. Scribe-marking reduced these properties, particularly ductility. As-received specimens fractured primarily along the $(11\bar{2}0)$ planes, whether specimens were taken longitudinally or transverse to the rolling direction. Preferred orientation developed during the rolling, with the (0001) basal planes parallel to the plane of the sheet, and a $[10\bar{1}0]$ direction parallel to the rolling direction. The $(11\bar{2}0)$ planes were normal to the tensile axis in transverse as-received specimens. This behavior is typical of materials with limited ductility – but the authors suggest the added possibility that the orientation changes as depth below the surface increases (this has been observed in other rolled hexagonal metals such as magnesium).

Figure 1 shows the tensile properties of as-received beryllium sheet

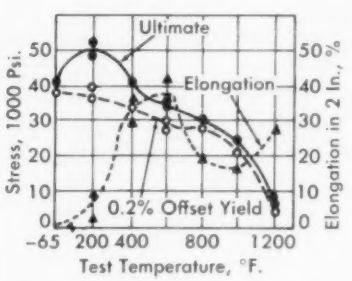

Fig. 1 – Tensile Properties of As-Received 0.060-In. Beryllium as a Function of Test Temperature

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Beryllium Sheet . . .

related to test temperatures. The increase in ductility from room temperature to 600° F. is thought to be due to $(10\bar{1}0)$ slip occurring more readily than (0001) slip as the temperature increases, as well as possibly along other planes of the $(10\bar{1}x)$ family. The decrease in ductility from 600 to 800° F. has not been satisfactorily explained, although one reference attributed this to a strain aging effect. The high elongation indicated at 1200° F. is not a true elongation: Actually metallographic examination showed that numerous micropores or microfissures had formed.

Room-temperature notched tensile strengths (specimens had a notch geometry with a stress-concentration factor of 4.4 ± 0.1) were lower than the corresponding average unnotched strength in both grain directions, for as-received, ground, ground and peened, and milled surfaces. Longitudinal specimens with etched and etched and scratched surfaces showed notched strengths better than the unnotched strengths for equivalent surfaces. These data indicate that beryllium sheet with a defect-free surface loaded in uniaxial tension in the longitudinal grain direction does not show undue notch sensitivity.

The S-N curves for tension-tension fatigue properties are straight lines contrasted to those of most structural metals. What might be considered the fatigue endurance limit is the same as the static strength of beryllium. Etched coupons withstood 10^7 cycles without failure, generally loaded to the average static strength. Ground coupons and etched and scribed coupons also lasted more than 10^7 cycles without failure at their somewhat lower static strengths. Peened specimens, on the other hand, failed at relatively few cycles, none reaching 10^7 reversals, indicating that the peening, as performed in this program, merely damaged the surfaces severely. This offset the beneficial effects of compressive stresses normally produced by shot-peening.

Room-temperature impact tests did not distinguish clearly between various surface preparations, since beryllium is quite brittle at room temperature. Since determination of the ductile-brittle transition temperature is an excellent way to evaluate the effects of various factors on the ductile-to-brittle behavior of other materials, it was also investigated in these tests. An impact energy of 50 in-lb. was obtained at −10° F. for the electropolished surface, at 300° F. for the ground surface, and at a temperature at least greater than 1110° F. for the shot-peened surface.

Residual stresses were measured for the various surface treatments of the beryllium. The residual stresses produced by a combination of thermal stresses, work hardening and twin formation would normally be expected to produce improved mechanical properties; but any such advantage is more than offset by the poor quality of the surfaces.

E. C. Miller

(*More digests on p. 198*)

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Deoxidizing Steel Melts

Digest of "Theory and Practice of Deoxidation of Steel", by by N. N. Dobrokhotov, *Izvestiya VUZ-Chernia Metallurgiya* No. 10, October 1959, p. 23-28; Brutcher Translation No. 4855.

BECAUSE OF THE VERY GENERAL APPROACH to the subject of inclusions in steel and especially those melts to which sufficient aluminum has been added to insure almost complete deoxidation, it is a little difficult to understand just how the author arrives at his conclusion. The early formation of silicates (which form with the oxidation of silicon when the charge is first melted), and the combination of these silicates with iron oxide, manganese oxide, and other compounds determine their tendency to remain in the melt as unwanted inclusions. If sufficient manganese is in solution and the temperature high enough to get the necessary fluidity, a large part of the silicate will combine as manganese silicates. Having a relatively low specific gravity, these compounds usually float to the top if there is good bath action. Oxidized aluminum also has a high affinity for silica at steel bath temperatures, and forms a refractory inclusion which is hard on cutting tools.

The effect of deoxidation on the sulphide types is well known since the part played by it has been carefully studied. On high carbon steels, the addition of about 1 lb. per ton of aluminum in the furnace before tap usually means quite complete deoxidation. It will generally insure the maximum of intergranular (film) type sulphides; any increase in aluminum above this will increase the globular type, and get rid of the film-type sulphides which are so harmful in their effect.

The author notes the increase in refractory inclusions, and their effects on the pouring practice. This is well known to every steel pouring crew handling heats to which 1 or 2 lb. of aluminum per ton has been added for "grain size" control. The greatly increased tendency for pouring nozzles to plug up is a difficult problem to overcome unless oxygen is injected freely at the right time.

In Russia the approach to prob-

(Continued on p. 204)

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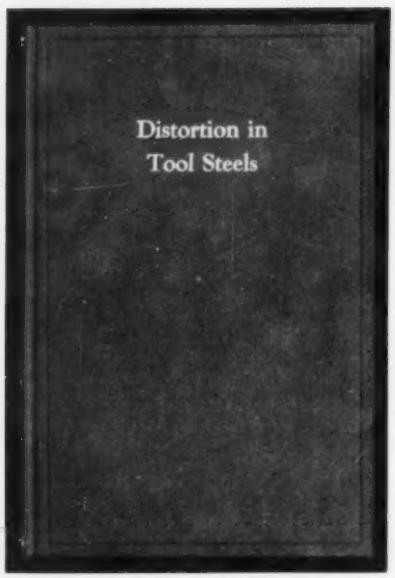
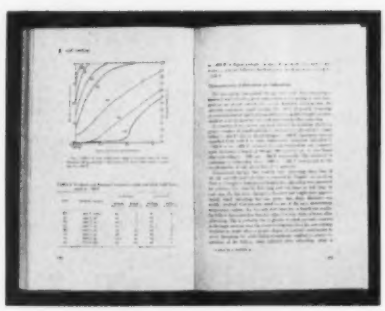
Circle 1242 on Page 48-S

DISTORTION IN TOOL STEELS





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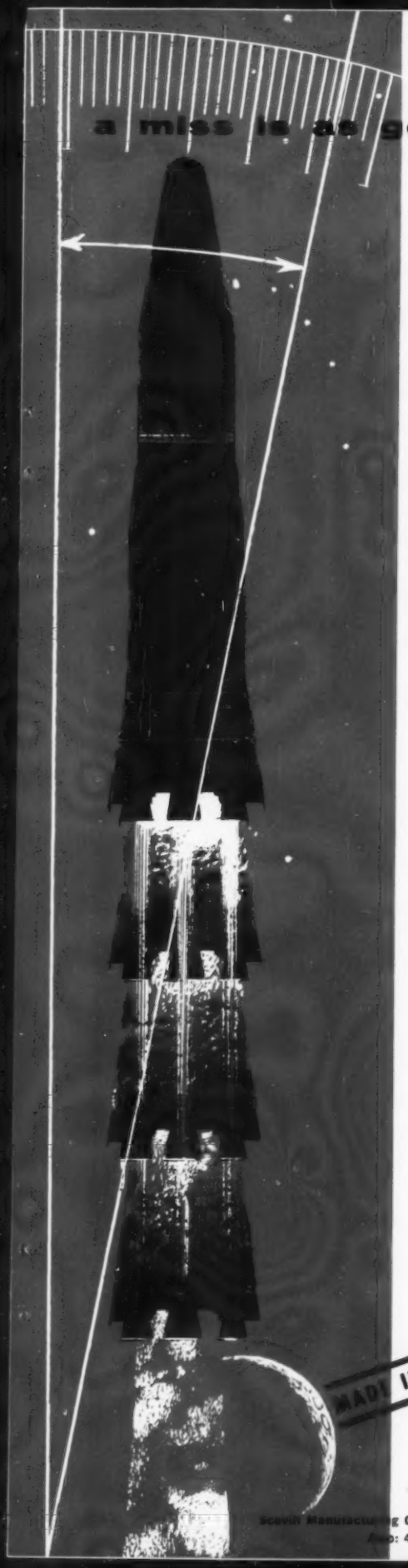

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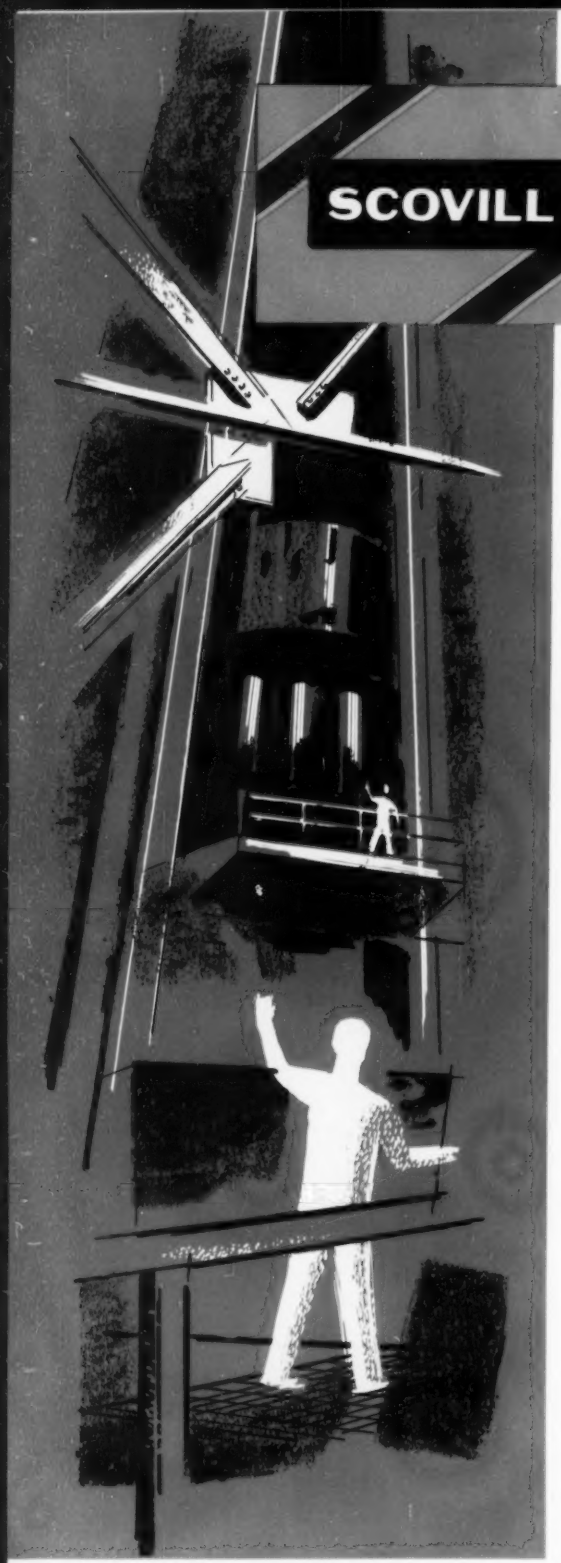

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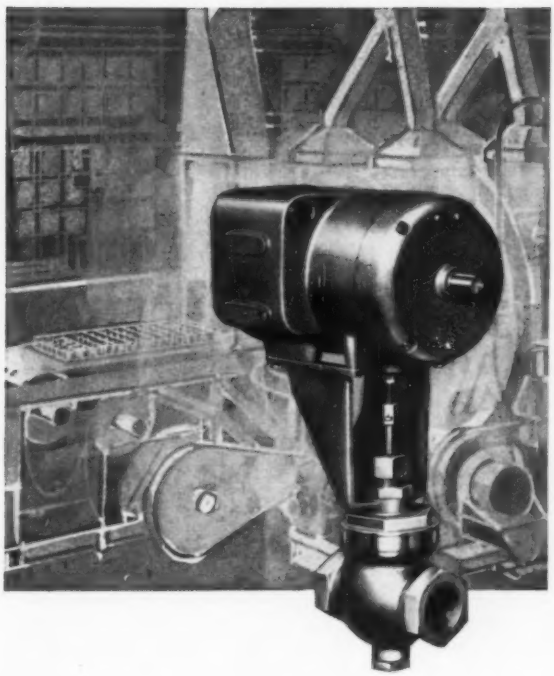

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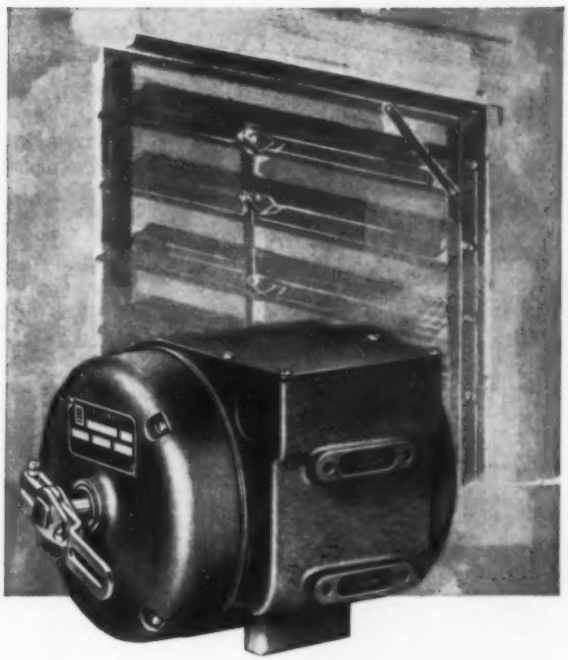

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Deoxidizing Steel . . .

lems involving inclusions, deoxidation products, and sulphides in ball bearing steel is interesting in that the problem was apparently satisfactorily solved by a few changes in melting practice and tests over a relatively long period in the actual production. The author's discussion of "ferrophobic" and "ferrophilic" deoxidation products is interesting, but he seems to have taken too general an approach to these products, without due regard to the variables in scrap meltdown analysis, melting furnace temperature ranges, bath action, slag fluidity, and other features. One of the big causes of the uncertainty in making special, extra clean, low-sulphur steels is the effect on the quality of any one of ten or more variables such as timing of additions, temperature of bath, bath activity, and the like. H. W. McQuaid

Bronzes for Pump Castings

Digest of "Cast 70/30 Cupro-Nickel Inherent Characteristics", by D. F. Shepherd, *Modern Castings*, May 1960, p. 120 to 130.

If one were looking for a typical example of alloy study, one could hardly do better than to choose this investigation of cupronickel-columbium alloy which developed because a better casting alloy was needed for pumps. Despite the many tests made on such bronzes, several angles had not yet been investigated. There was also a need for some additive to control and offset the antiwelding effect of silicon.

Some Preliminaries

High-pressure pumps needed these characteristics: lighter cross section, greater strength, good anticorrosion properties under a varying condition of still, moving, and high velocity liquids, and good welding quality. Though the Navy *M* and *G* alloys have served well in the past, today's needs call for alloys with better properties. The wide freezing range of these alloys meant difficulty in foundry practice in order to avoid porosity and gas.

As for the actual work, the author tested an alloy made in a 600-lb.

Bronzes . . .

basic-lined induction furance; the material gave 32,000 psi. yield and 60,000 psi. tensile. The silicon content ran between 0.70 and 0.50%, and iron 0.25 to 0.60%.

However, as the silicon increased, weldability deteriorated. Attention was then turned to the possibilities of columbium. Between 0.33 and 0.83% Cb produced an alloy with good weldability. A special homogenizing heat treatment raised the yield point to 54,000 psi, the tensile to 87,000 psi. Elongation was 20% and Brinell hardness was 167. The homogenizing treatment consisted of heating for 5 hr. at 1200° F. and then slowly cooling in the furnace to 500° F. or lower.

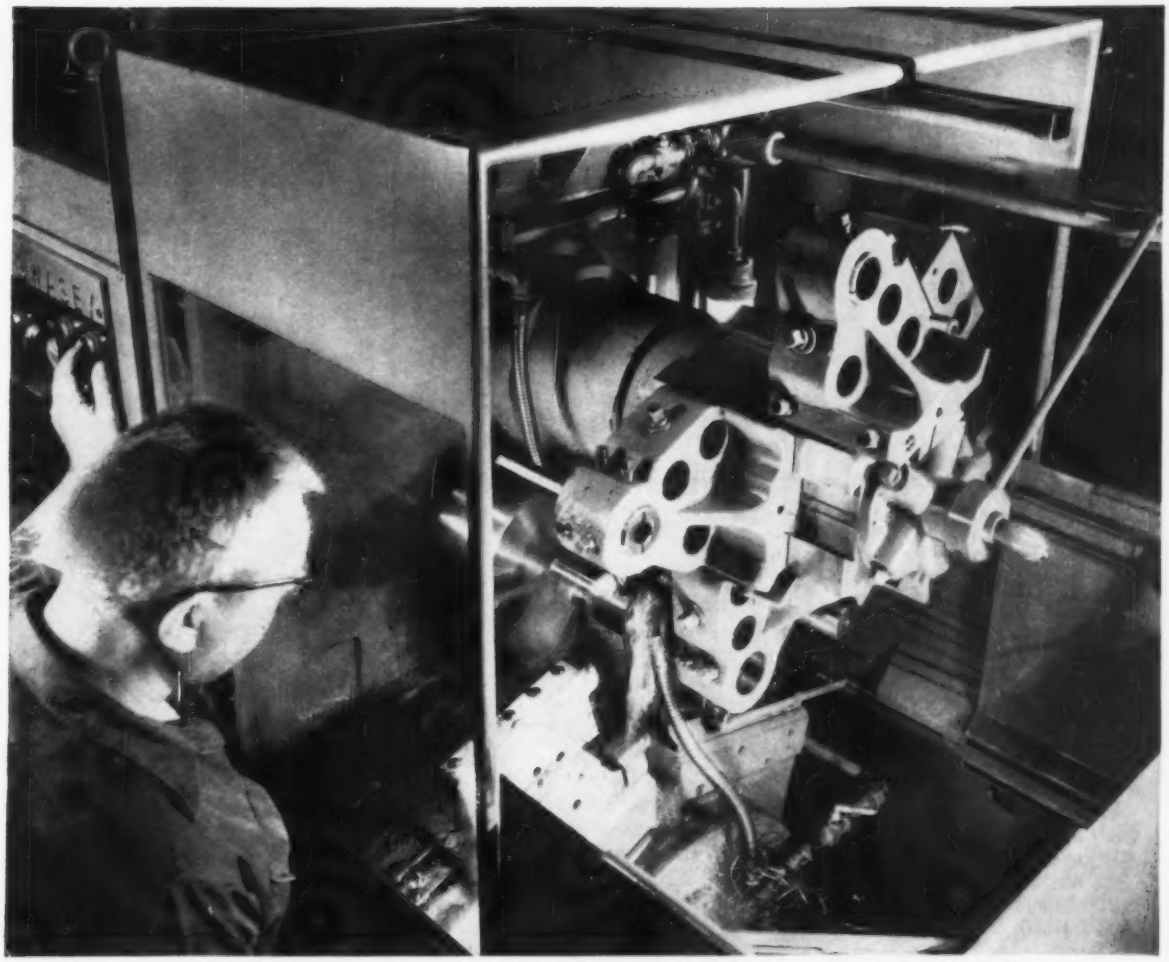
That slow cooling increased the physical constants was naturally a matter of surprise. But the fact remained that the test bars taken out of the mold 20 min. after pouring (when they were about 1400° F.) and cooled in air had properties much lower than they did when slowly cooled. As a consequence, all subsequent test bars were left in the mold until cold. (Lack of knowledge of this peculiarity may be the reason that other operators found it difficult to get consistent results in the earlier runs of 70-30.)

The next step was to give the test bars a homogenizing treatment by putting them in an electric furnace and holding them for 5 hr. at 1200° F., and then allowing them to cool *slowly* to 500° F. or lower. Applying this slow cooling treatment to castings enables their thin sections to come more closely in line with the stronger, heavier sections. Further tests were made to see whether a greater mass would affect test bars. The result? Even the slight increase in mass for the 1-in. Y-bar gave higher properties than the Webbert bar, and similar bars cast in a copper mold (which would cool faster) gave consistently lower values. The "cast to size" bars of both Webbert and Inco also gave low results. Test bars taken from castings weighing some 4000 lb. gave good results compared with their control test bars. Since these castings were large enough to give a homogenizing effect by slow cooling, little difference was found between them and the control test bars.

The welding quality of this new alloy was carefully investigated. Test bars made up by welding gave 26,000 psi. yield and 52,000 psi. tensile; these are considered to be good values.

The narrow composition of this new alloy requires accurate foundry control. This was provided in the author's foundry by using a direct-reading X-ray fluorescent spectrograph which enabled the tests for five elements to be completed in between 6 to 7 min., while the metal was held in the furnace for any necessary correction.

The author concludes that the desirable foundry characteristics of 70-30 cupronickel, particularly in thick sectioned castings, are accompanied by a sensitivity of physical properties and weldability as a function of chemical composition and cooling rate. Weldability is improved and physical properties in-



Rigidity and accuracy built into this Warner & Swasey 2AC chucking automatic permit heavy metal removal while holding close tolerances. Twenty-one parts made from AISI 4340 and 4615/20 steels contribute resistance to stress and wear in critical areas.

Warner & Swasey uses two nickel alloy steels to give the 2AC built-in rigidity and accuracy

Variety of parts made from 4340 and 4615/20 for long-term resistance to impact and wear.

Here's where the Warner & Swasey Company relies on AISI 4340 and 4615/20 to help maintain the rigidity and accuracy for which this 2AC single spindle chucking automatic is fast becoming famous.

Four clutch plates, for example, are made of 4340. Through-hardened for these parts, this 1.85% nickel steel provides dimensional stability in heat-treatment and in high-temperature operation . . . in addition to vital resistance to shock-loading and torsion.

Shafts, guide blocks, studs, plungers, and clamp strips are just a few of the parts in the versatile 2AC made from another nickel alloy steel: AISI 4615/20. These components are carburized and hardened for wear-resistance to maintain accuracy throughout a long service life. And the *uniform* hard case is backed up by a strong, tough core that stands up to severe impact and torsional stresses.

This report is typical of the many coming in from manufacturers who have employed these two General Purpose Steels for a variety of machinery components.

Both these steels are readily available, right off the shelf at your local Steel Service Center. Together they give you a double-barreled way to cut costs and still satisfy almost all your alloy steel needs. Other nickel alloy steels, possessing special properties for specialized applications, are also widely available.

Consider nickel alloy steels for gears, shafts, bearings, and other machine parts you design, order, or use. And for engineering information to help you select the right material for the job you have in mind, just write to Inco.

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street INCO New York 5, N. Y.

INCO NICKEL

NICKEL MAKES STEEL PERFORM BETTER LONGER

Bronzes . . .

creased (for any given silicon content) by additions of columbium. Fast cooling through the red heat range reduces physical properties, heavier sections of castings showing higher strength values due to the slower cooling. (The latter finding is the usual assumption.) The maximum properties inherent in the composition can be developed by reheating to approximately 1200° F. and cooling to 500° F.

H. J. Roast

Automatic Temperature Control

Digest of "Automation of Temperature Control in Melting of Nonferrous Alloys", *Tsvetnie Metalli* (Nonferrous Metals), No. 9, 1959.

Automatic temperature controls now help nonferrous alloys at the Kolchugin Works. It is well known that even a large staff of pyrometric observers cannot insure accurate temperature control when casting hundreds of heats per day. Casting of "cold" and "hot" melts results in defects subsequently revealed during rolling, press and drawing operations. To prevent such defects, two schemes have been adapted. Both are based upon brief immersion of thermocouples in the metal. The method is similar to that used in steelmaking practice. However, the temperature measurements will be registered not only on recorders, but also on a controller which will confine casting of metal to a sharply defined temperature range, controlled by an electronic potentiometer.

Two furnaces have been equipped by such an arrangement. A platinum/platinum-rhodium thermocouple with a protective molybdenum tip is immersed into the molten metal by an electrically driven mechanism controlled by the operator.

An alternative scheme consists of several relays and a potentiometer, signal lamps, and sirens in a circuit with the operational control system of the induction melting furnaces. The control arrangement is connected to the furnace operating pulpit by an eight-ply control cable.

KNOW YOUR ALLOY STEELS . . .

This is one of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many who may find it useful to review fundamentals from time to time.

When Should Alloy Steels Be Ordered to Hardenability?

What is hardenability and how does it differ in carbon and alloy steels?

Hardenability can be defined as the capacity of steel to develop a desired degree of hardness, usually measured in depth. It is produced by special heating and cooling. Carbon steel, except in small sections, will normally harden to a depth slightly below its surface, while alloy steel can, under certain conditions, harden uniformly through its entire cross-section.

Surface hardness obtainable after quenching is largely a function of the carbon content of the steel. Depth hardness, on the other hand, is the result of alloying elements and grain size, in addition to the carbon present in the steel.

In general, where hardenability is the prime consideration, it is not too important which alloy steel is used, just so long as there is sufficient carbon present to give the prescribed hardness, and there are enough alloying elements to quench out the section. It is not considered good practice to alloy a small section excessively, since excessive use of alloying elements adds little to the properties and can, in some instances, induce susceptibility to quenching cracks.

There are, of course, numerous cases where factors other than hardenability must be considered; such factors as low-temperature impact, heavy shock, creep-resistance, and the ability to resist temper brittleness. Through-hardening, therefore, is not always desirable. For example, shallow hardening is often necessary in shock applications, because a moderately soft core is essential.

This series of alloy steel advertisements is now available as a compact booklet, "Quick Facts about Alloy Steels." If you would like a free copy, please address your request to Publications Department, Bethlehem Steel Company, Bethlehem, Pa.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.
Export Sales: Bethlehem Steel Export Corporation

BETHLEHEM STEEL

Circle 1250 on Page 48-S

Temperature Control . . .

Six furnaces, including two capable of a maximum melting temperature of 1300° C. (2370° F.) and one three-phase induction furnace, have been thus equipped. A Chromel-Alumel* thermocouple is connected to the regulating and recording potentiometer.

Thermocouple tips of molybdenum are used for temperatures up to 1300° C. (2370° F.). An alternative to molybdenum is heavy-walled quartz. The gray iron tips are good for 100 to 150 measurements and molybdenum tips for 250 to 350 measurements.

*Registered trade mark, Hoskins Mfg. Co.

A staff of pyrometricians is thus eliminated since metal casting will occur at a definite temperature. At this temperature, the siren toots, the green signal lamp flashes, and the relay closes. The latter controls the furnace tilting mechanism, and metal pouring starts.

The melter does not need to note the melt temperature since it is automatically recorded on the potentiometer diagram. "Cold" and "hot" are signaled by yellow and red lamps, respectively, and pouring is prevented by disconnecting the furnace tilting mechanism, making it impossible to pour at incorrect temperatures. The relay scheme also prevents the furnace from tilting if the thermocouple measurement is too short in duration for accuracy.

During furnace loading, the thermocouple is placed outside the furnace. Upon melting, the operator places the thermocouple into the furnace and then starts to prepare the next furnace charge. When the required temperature is reached, the potentiometer instantaneously disconnects the furnace through relays. After 9 to 10 sec., it connects with the signalling system circuit of the furnace tilt controls. After the signal, the operator withdraws the thermocouple and switches to the electric controls of the furnace tilt.

Further improvements in this method are being sought. These include selection of a new material for the thermocouple jacket, one which would not be affected by permanent immersion in the molten metal. This will eliminate the need for manual immersion by the operator. This material should possess high thermal conductivity.

ARTHUR B. TESMEN

New Metallographic Techniques

Digest of "Electrochemical Techniques in Modern Metallography", by Pierre A. Jacquet. Paper presented at the Golden Jubilee Convention of the American Electroplaters' Society, June 1959, Detroit.

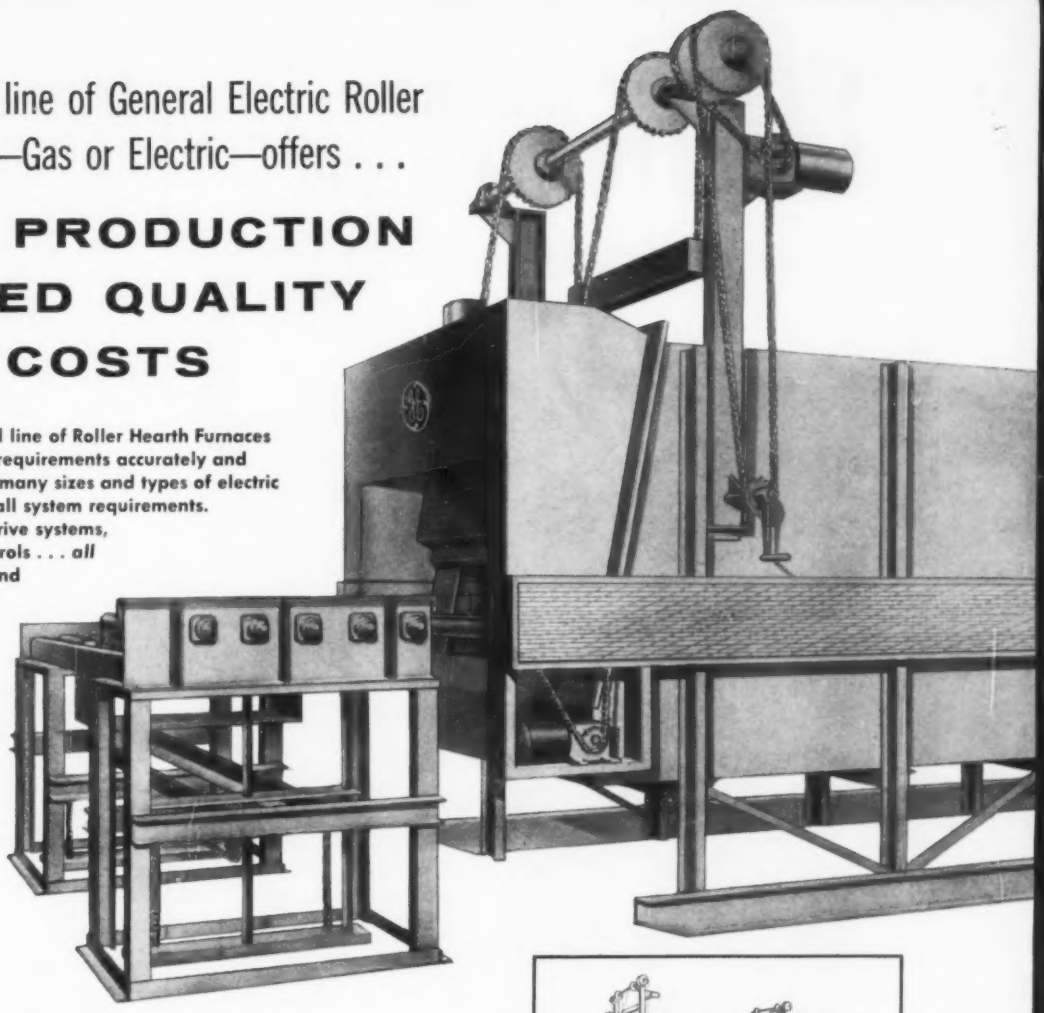
IN 1935, GENERAL PROCEDURES for electropolishing a wide variety of materials were published. Further impetus for the development of electrolytic polishing procedures was provided by World War II. Improved techniques resulted, and eventually electropolishing techniques were accepted in research work. Electropolishing has also helped such techniques as phase contrast microscopy, interferometry, microhardness studies and particularly electron microscopy.

With acceptance of electropolishing, commercial electropolishing machines were made available. In 1956, a simple portable polishing cell was devised which could be applied locally to any accessible areas to reveal microstructures. Microscopic examination of irregular and often inaccessible surfaces was also a major problem. It was solved by a technique for forming replicas of the structures. These replicas can be

NEW complete line of General Electric Roller Hearth Furnaces—Gas or Electric—offers . . .

HIGHER PRODUCTION
IMPROVED QUALITY
LOWER COSTS

General Electric offers a full line of Roller Hearth Furnaces to meet your heat treating requirements accurately and economically. Choose from many sizes and types of electric or gas-fired furnaces to fit all system requirements. Cooling sections, roll and drive systems, interior doors, burners, controls . . . *all* components are designed and built to best complement your system efficiency.



Look At These Outstanding Design Features of General Electric Roller Hearth Furnaces

• **Application Versatility**—A choice of four types of heating sections, five types of cooling systems, two roll and bearing systems, and a host of sizes and accessories.

• **Quick, Easy Installation**—Furnace sections are completely assembled at the factory with brick, heating units, piping, wiring, and rolls already in place.

• **Fast, Top Quality Production**—The advanced construction design features of these General Electric furnaces let you increase both the quality and rate of your production.

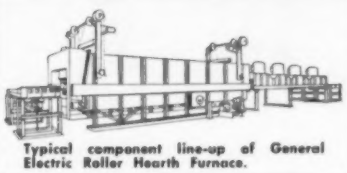
• **Continuous, Unlimited Work Flow**—The G-E Roller Hearth Furnace conveyor system consists of a series of externally driven rolls—no belts or pusher mechanisms are required.

• **Trouble-free, Long-life Operation**—Individual conveyor rolls are externally driven and remain in the same temperature zones . . . not subject to thermal cycling.

• **Flexible Operation**—Individual roll sections can be started, stopped, reversed, or oscillated; they can be run at the same or different speeds.

• **Lower Product Costs**—Wide selection of furnace combinations and sizes means you can get the furnace designed for your needs. You can cut costs through improved product quality and production rates.

Call your General Electric Sales Engineer today. He's an expert in applying G-E Roller Hearth Furnaces. Contact him at your nearby General Electric Sales Office, or write for Bulletin GED-4304, to Section 756-11, General Electric Co., Schenectady 5, New York.



Typical component line-up of General Electric Roller Hearth Furnace.

THERE'S A GENERAL ELECTRIC FURNACE FOR THESE HEAT TREATING PROCESSES

Cycle Annealing. This furnace may be heated by electric ribbon resistors or by gas-fired radiant tubes, and will normally have a controlled atmosphere to prevent scaling and surface decarburization.

Copper Brazing and Sintering. Both copper brazing and sintering furnaces are operated with a reducing atmosphere to prevent oxides from interfering with the brazing or sintering operation.

Magnetic Punching and Lamination Annealing. This furnace is operated with a carefully selected controlled atmosphere and heating may be either by gas fired radiant tubes or electric ribbon resistors.

Hardening. This furnace operates with a non-decarburizing protective atmosphere and may be equipped with an integral elevator type quench system or the work may be delivered to hand, die, or press quenching.

General Heat Treating. These furnaces are ideal for full anneal of steel castings and for stress relief anneal of castings or forgings. They may be gas fired direct, gas radiant tube, or electric ribbon resistor heated.

Progress Is Our Most Important Product

GENERAL ELECTRIC

Circle 1252 on Page 48-B

Metallographic . . .

stripped from the surface and subjected to optical or electron microscopic examination. Thus surface macrostructure, microstructure and submicrostructure may be critically examined regardless of the size, shape or location of the object, without damage to the part.

Electropolishing depends upon the solution of surface projections and heterogeneities without preferential extraction of atoms from the normal or disturbed crystallographic lattice. Thus, an originally rough anode may be polished. Success of the procedure depends upon the selection of an appropriate electrolyte and suitable electrical conditions. One of the most important advantages of electropolishing lies in the complete absence of worked layers.

The electrolytic method, however, does require a suitable cell, a controlable source of power, and a sample which is small enough so that the critical current density can be obtained. The use of available commercial machines greatly simplifies the problem of conveniently obtaining the critical conditions necessary for polishing.

Etching may be done by a number of methods. Electrolytic etching is useful under the following conditions:

1. In polishing solutions under specific electrical conditions where microstructure is revealed by etching the contours of the grains, selective solution or corrosion of the grains, or preferential etching of irregularities in the crystallographic lattice.

2. In polishing electrolytes by short circuiting the electrodes at the end of the polishing cycle.

3. In aqueous acid, alkaline, or salt solutions under suitable electrical conditions.

4. In anodic oxidation techniques which form epitaxial films on certain metals.

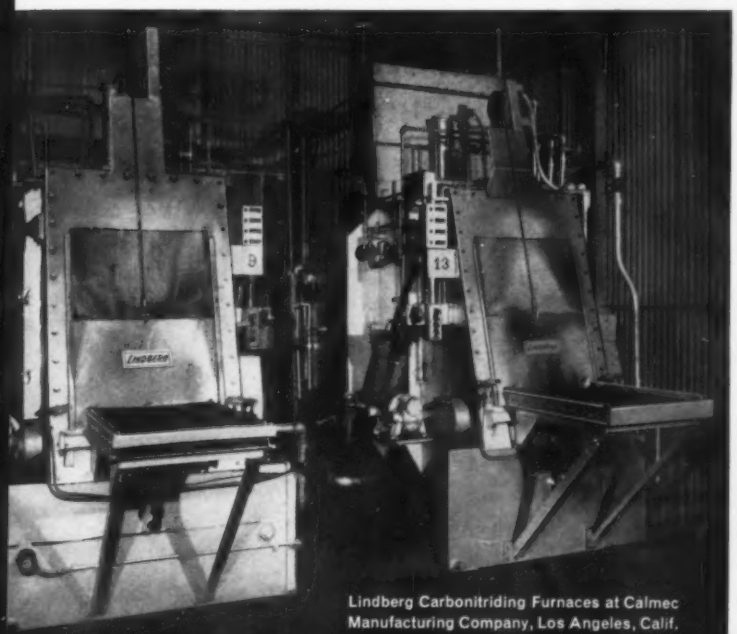
A portable apparatus has been devised for local electrolytic polishing. It consists of two parts, the power supply with its devices for controlling the electrical factors, and the polishing electrode with its accessories.

The electrode, or movable cathode, has a stainless steel head attached to the end of an insulated

J. F. McINTYRE tells why CALMEC always looks to Lindberg for heat treating equipment

Left, S. E. Summers, Chief Design Engineer and at right, J. F. McIntyre, Executive Vice-President, Calmec Manufacturing Company, Los Angeles. In the Middle, J. E. Krickl, Western Sales Manager, Lindberg Engineering Company.

"When we have heat treating problems we like to get the Lindberg man right in the middle of them. We know Lindberg men are heat treating experts and the best source we have for advice on the most practical and efficient equipment to satisfy any heat treating requirement. As a result we've bought lots of Lindberg equipment in the past few years. We like it and the fact that we are continuing to buy it proves that the Lindberg man's advice has been sound."



Lindberg Carbonitriding Furnaces at Calmec Manufacturing Company, Los Angeles, Calif.

Mr. McIntyre has certainly backed up the above words with deeds. Over the past few years, Calmec, a leading manufacturer of precision tools, parts and missile system components, has installed twelve electrically heated furnaces, six gas-fired furnaces and four atmosphere generators—all Lindberg! And we hope there are more to come. If you have any product or process in the metal or ceramic field requiring the application of heat it would be a good idea to get the Lindberg man in the middle right away. You can depend on his experienced help and Lindberg's engineering and design know-how to provide exactly the right equipment for your need. It's easy! Just get in touch with your Lindberg Field Engineer (see your classified phone book) or write us direct. Lindberg Engineering Company, 2448 West Hubbard Street, Chicago 12, Illinois.

Los Angeles plant: 11937 S. Regentview Avenue, Downey, California. In Canada: Birlefco-Lindberg Ltd., 15 Pelham Ave., Toronto 9, Ont. Also, Lindberg plants in Argentina, Australia, England, France, Italy, Japan, South Africa, Spain, Switzerland and West Germany.

Circle 1254 on Page 48-B

LINDBERG
heat for industry

Metallographic . . .

sleeve and traversed by a current of cooling water. A cap of synthetic fabric fits the head. This fabric cap must be flexible, electrically insulating, and capable of holding the required small amount of electrolyte. It must not be attacked by the electrolyte. Special electrolytes are required for polishing.

Although the tampon was originally devised for polishing the surface of test samples or parts whose geometry did not permit the use of an ordinary polishing cell, it has been found to have numerous advantages over other polishing methods. It is extremely simple, it can locally polish any shape or size of material, and it eliminates deep etching at the periphery of the polished zone.

The second phase of nondestructive metallography involves the preparation of suitable replicas for microscopic examination. A varnish, which consists of nitrocellulose, solvents and plasticizers is applied to the prepared surface. When the film is dry, it is stripped from the surface. This technique will reproduce surface irregularities of the order of 10 to 20 A. The replicas are examined with the microscope either by transmitted or incident light. Reflectivity of the replica can be increased by evaporating a very thin layer of aluminum on its surface; this is necessary when very high magnification is required. Replicas can be adapted to electron microscopy by evaporating a layer of alumina or carbon on them. This produces a negative replica which is handled in the usual manner.

R. L. ANDERSON

Effect of Thermal Cycling on René 41 and Astroloy

Digest of "Structural Damage in Thermally Cycled René 41 and Astroloy Sheet Materials", by D. P. Moon, J. A. VanEcho, W. F. Simmons and J. F. Barker, DMIC Report 126, Feb. 29, 1960, Defense Materials Information Center, Batelle Memorial Institute.

THE QUESTION OF DAMAGE caused by cycles of alternate heating and cooling in flight is of great importance for materials in high-speed aircraft. It is particularly pertinent in precipitation hardened alloys which, during cycling, may encounter temperatures greater than normal operating temperature. To answer this, a study was made on René 41 and Astroloy, two precipitation hardened nickel-base alloys. Tested in the form of 1/16-in. thick sheet, treatment consisted of soaking briefly at 450° F., loading to specified stress, heating to 1350° F., and thermally cycling. Each thermal cycle consisted of holding at 1350° F. for 60 min., heating to the upper test temperature in 30 sec., holding at temperature for 15 sec., and cooling to 1350° F. in 30 sec. The upper test temperature was 1875° F. (an "A" cycle) or 1750° F. (a "B" cycle). René 41 specimens were exposed to 10 and 100 "A" cycles under a stress of 3000 psi. and to 10 to 100 "B" cycles under a stress of 6000 psi. Astroloy specimens were exposed to 10 "A" cycles under a stress of 5000 psi.

MUD was rough on oil drill nozzles!

Abrasion was causing hardened steel and even special alloy mud nozzles to wear out too fast. A metal exceptionally resistant to the scouring action of drilling mud was needed.

V-R CARBIDE solves the problem

Nozzles made of V-R carbide now far exceed the life of previously used metals. This is an example of creative engineering at Vascoloy-Ramet where metals are developed to meet physical specifications. Characteristics such as abrasion and corrosion resistance, dimensional stability, high density and strength are properties that are produced in varying degrees in V-R sintered or alloyed metals. Send us your specifications for your custom metal needs.

V-R

CREATING THE METALS THAT SHAPE THE FUTURE

VASCOLOY-RAMET

848 MARKET STREET • WAUKEGAN, ILLINOIS

A-827

Circle 1256 on Page 48-B

Thermal Cycling . . .

Exposure of René 41 to 10 "A" cycles under a stress of 3000 psi. has no significant effect on the stress-rupture life (20,000 psi.) at 1650° F. One hundred "A" cycles under the same conditions decreased the stress-rupture life on the order of 15%. Ten "B" cycles increased the stress-rupture life about 25% while 100 "B" cycles increased it about 15%. Under all four sets of conditions there was significant decrease in tensile and yield strengths at room temperature and 1400° F.

Exposure for 10 "A" cycles caused agglomeration, migration to grain boundaries, and partial resolution of the $Ni_3(Al, Ti)$ precipitate. Simultaneously, there was noticable oxidation and alloy depletion on the surface. After 100 "A" cycles, resolution of the $Ni_3(Al, Ti)$ precipitate was nearly complete, and alloy depletion was more extensive. After exposure to the "B" cycles, overaging was apparent.

Exposure of Astroloy to 10 "A" cycles under a stress of 5000 psi. had no significant effect on tensile and yield strengths at room temperature and 1400° F. Stress-rupture life (30,000 psi.) at 1650° F. was increased on the order of 35%. However, noticeable overaging of the alloy in addition to oxidation and alloy depletion on the surface indicates the possibility of significant damage with additional cycling.

C. O. Smith

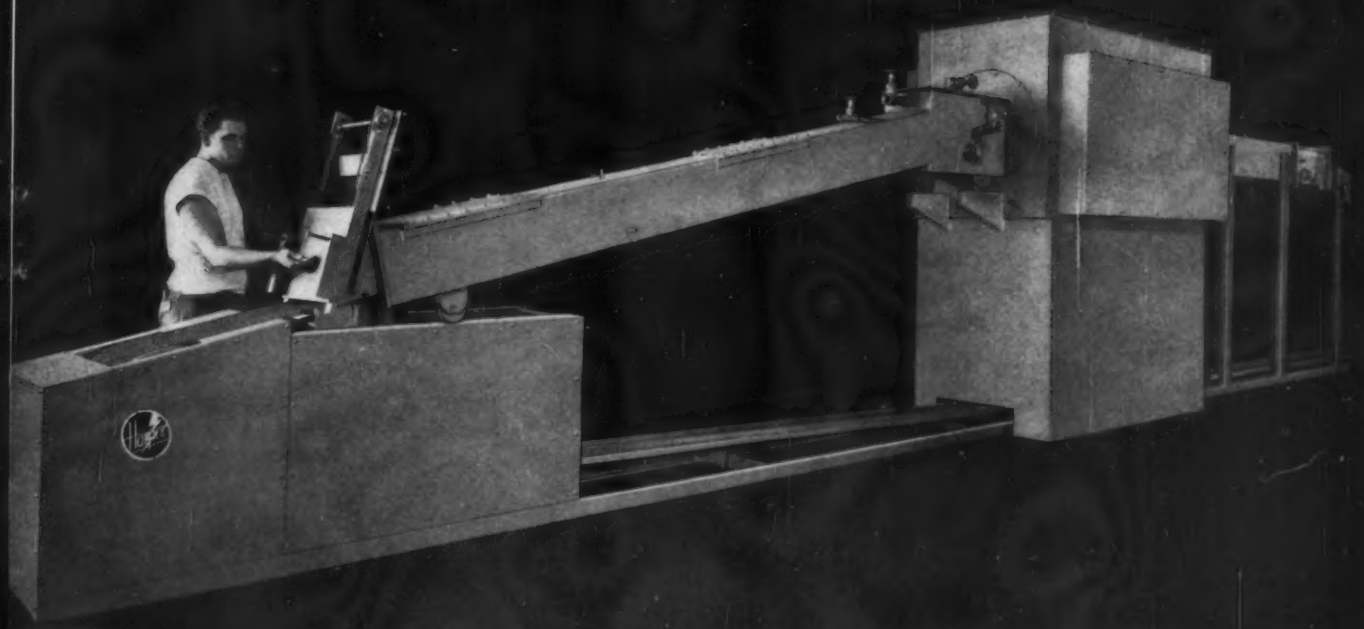
Vapor Deposition of Metal

Digest of "Vapor-Phase Deposited Metal Coatings on Induction-Heated Steel", by Yu. V. Grdina and L. T. Gordeeva, *Izvestiya VUZ-Chernia Metallurgiya*, No. 7, July 1959, p. 97-100; Brutcher Translation No. 4766.

High-frequency currents can be used to heat metals being vapor plated. In fact, induction heating accelerates the processes taking place in steel thus heated. In addition, induction heating has a number of specific advantages:

1. The component can be heated to only the depth required. Thus, the underlying metal can be given,

PROCESSING A VARIETY OF METALS:



LOW DEW POINTS HELD FOR CRUCIAL WORK

Shown above is Harper's new version of the hump-type mesh belt furnace. Featuring several design innovations and improvements, it's engineered to provide low dew point atmospheres for continuous brazing, annealing, hardening, and sintering.

Materials to be treated can be light or medium weight — in multiple sizes and shapes. The work can be loaded directly on the belt or in lightweight baskets or carriers. With the elevated heating chamber providing a natural atmosphere seal, far less hydrogen or dissociated ammonia is consumed than with a straight-thru furnace. Variable speeds permit treatment of materials of different thicknesses and time-temperature requirements.

Available in both electric and gas heated models, these modernized hump-type mesh belt furnaces are ideally suited for processing a variety of metals in the electronic, aircraft, guided missile, space vehicle, nuclear energy, and other fields. They're representative of the way in which Harper is continually updating its complete lines of box, pusher, mesh belt, roller hearth, bell and elevator furnaces.

Detailed information can be obtained by writing for new illustrated Bulletin HMB-60. Harper Electric Furnace Corp., 40 River St., Buffalo 2, N. Y.

HARPER ELECTRIC AND GAS FURNACES

FOR BRAZING, SINTERING, ANNEALING, HARDENING, AND FORGING IN RESEARCH AND PRODUCTION

Circle 1259 on Page 48-S

Vapor Deposition . . .

by a preceding treatment, the best possible structure and properties.

2. Because of the high temperature and the short holding time, the surface of the metal or alloy can be saturated with the plating metal to the fullest extent.

3. It is simple to heat treat only certain parts of the component if necessary. Long objects, such as tubes, strip, and wire, are also easily treated.

Since induction heating holds considerable promise, processes for gas carburizing and cyaniding have already been devised. Work has also covered spray coating with liquids and metal coating with pastes, the workpieces being induction heated.

This paper describes diffusion coating with chromium, aluminum, silicon, tungsten, molybdenum and also chromium-aluminum combination coating from chloride atmospheres of Armco iron, carbon steel with 0.64% C, and special alloys.

For induction heating, 40 kiloamp. and a frequency of 500 cycles per sec. was used. The specimen was placed into a silica tube through which chlorides of the coating metal were passed. Gaseous chlorine was obtained by reaction of concentrated hydrochloric acid with potassium permanganate. After cleaning and drying, this chlorine passed into the heated furnace where it reacted with the metal powder already there (having been placed in the furnace before). The metal chlorides then passed on through a tube to the specimen and enveloped it; the coating was formed when the chloride decomposed.

In subsequent tests, the metals were in the pure powder form or as high-percent ferroalloys. Before coating, specimen surfaces were ground and cleaned with benzene or alcohol. Gaseous chlorides were formed at 600 to 650° C. (1110 to 1120° F.) for aluminum, and at 940 to 960° C. (1725 to 1760° F.) for the other metals. The specimens were held, during the coating operation, for 8 to 30 sec. at 1000 to 1100° C. (1830 to 2010° F.) with intermittent current. When coating with silicon, chromium and aluminum, the authors obtained diffusion coatings about 0.2 mm. (0.008 in.) deep within 8 to 9 sec. When coating with tungsten, a layer of the same depth required 15 sec.

Metallographic examination of chromium coatings revealed a continuous bright surface layer consisting of a solid solution of iron and chromium. Toward the interior, there is an intermediate dark-colored layer of eutectic (or eutectoid) joining the first layer with the core. The dark layer usually becomes more pronounced and thicker as the carbon content increases.

In conclusion, it is possible to coat (by gas diffusion) such metals as chromium, aluminum, molybdenum, tungsten, silicon and chromium-aluminum jointly on induction heated steel. The rate is several hundred times higher than that for furnace heating. C.R.W.

Strain Energy Criterion for Fatigue Failure

Digest of "Micro-Plastic Strain Hysteresis Energy as a Criterion for Fatigue Fracture", by C. E. Feltner and J. Morrow. Paper 60-MET-2, presented at the A.S.M.E.-A.W.S. Metals Engineering Conference, April 1960, Los Angeles.

FATIGUE DESIGN IS PRIMARILY BASED on a stress criterion with allowable stresses obtained from an S-N curve determined under conditions ap-

SIGMATIC

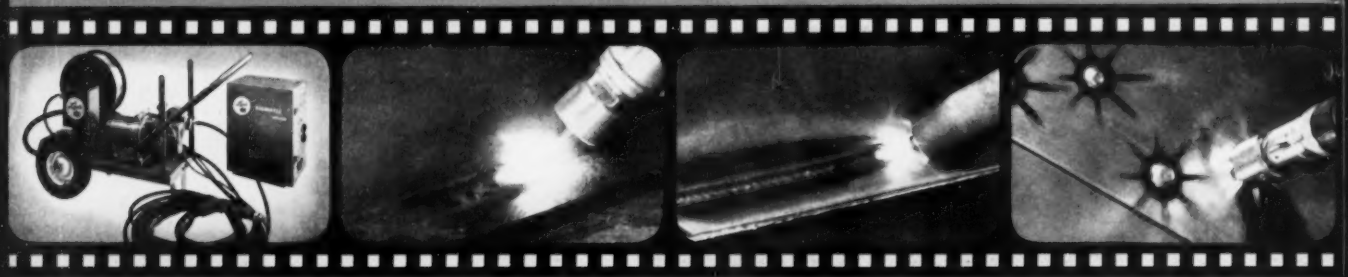
NEW ALL-IN-ONE "MIG" WELDING EQUIPMENT

Welding equipment is designed, developed and refined, but eventually it must be redesigned. LINDE'S new SIGMATIC line of "Mig" welding equipment is a product of this evolution . . . plus LINDE'S vast experience with more inert-gas and consumable-electrode processes than any other company in the world. The SIGMATIC line is the most-versatile semi-automatic equipment available anywhere—one machine for:

- **. . . all types of "Mig" welding—spray arc, short arc and spot welding**
- **. . . in all welding positions—vertical, overhead or downhand**
- **. . . with all shielding gases—argon, helium, CO_2, or their mixtures**
- **. . . and all wires—hard or soft, solid or tube**
- **. . . on all weldable metals—carbon steel, stainless, aluminum, magnesium, titanium**
- **. . . on all thicknesses—sheet metal and up**

See next page for details.

SIGMATIC



One SIGMATIC machine for... spray arc... short arc... spot welding

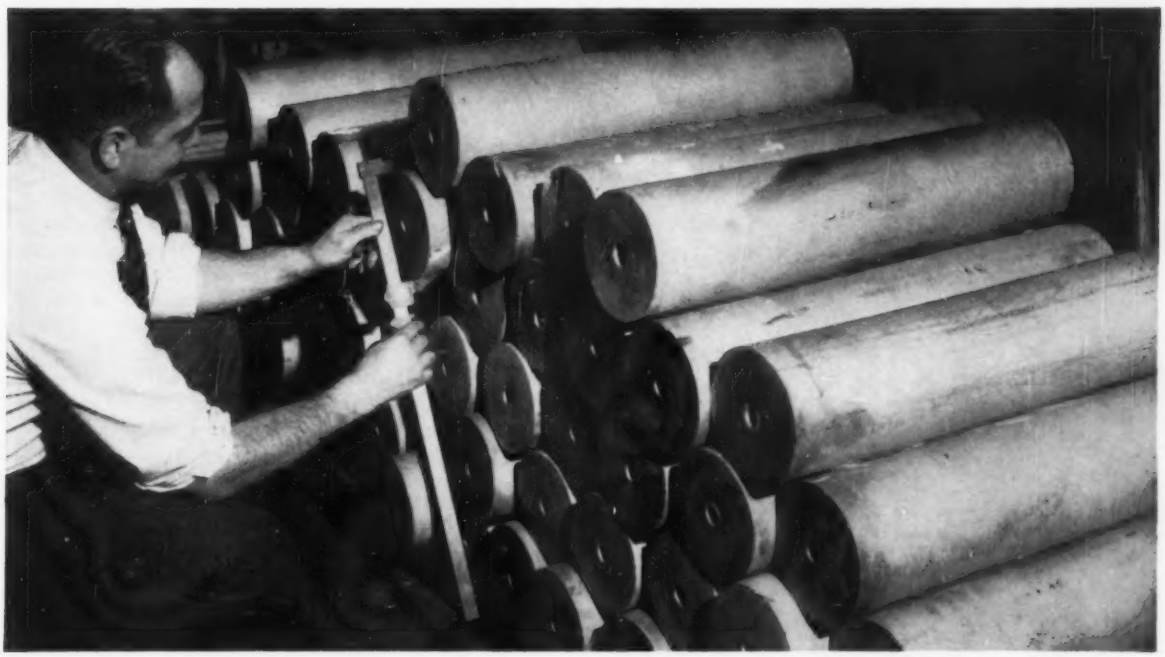
Spray arc, short arc, spot welding... never before combined in a single piece of equipment. SCC-8 control incorporates special spot-welding circuitry, featuring a directly-calibrated, precision weld timer and an independently-adjustable, "non-stick" timer. Converts from spot to continuous fusion welding at the flick of a switch. SEH-2 heavy-duty wire-feed unit—largest, most-rugged unit available today—permits positive feed of all "Mig" wire types, metals and diameters. The SIGMATIC line contains five basic units, designed with interchangeable parts permitting more than 50 combinations tailor-made to individual specifications. Available in cart-, sled- or bench-type units.

Unique controls are vastly simplified. All components are visible and accessible. Adjustments can be made with a screw driver. Only heavy-duty industrial-type parts are used throughout each unit to insure dependable, long-life performance with minimum maintenance. Top-quality parts—"Square D" pneumatic timers, Mallory electrolytic condensers, Cutler-Hammer switches, Potter & Brumfield relays, Electrons, Inc. thyratron tubes. The SIGMATIC line is unquestionably a major welding advance—with one rugged, durable machine, you can do any type of "Mig" welding in any position on any thickness of any metal. For more information or a live demonstration, call your nearest Linde office.

LINDE COMPANY UNION CARBIDE

Division of Union Carbide Corporation
270 Park Avenue, New York 17, N. Y.

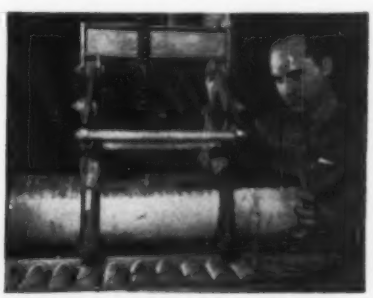
MASSIVE TUNGSTEN AND MOLYBDENUM
New, big-size G-E Refractory Metals



General Electric PS Moly and PS Tungsten are pure metal powders, prepared by hydrogen reduction, cold pressed hydrostatically into basic products and strengthened by sintering in a high temperature hydrogen furnace. You can now get pure PS (Pressed and Sintered) G-E Molybdenum and Tungsten in a variety of large shapes. For example—they're available as forging billets, consumable electrodes for vacuum arc melting, simple preforms, sheet slabs, tubes and other basic forms to fit just about any application for these unique metals in massive form. Plan now on PS metals from General Electric. Write for more information. General Electric Co., Lamp Metals and Components Dept., MP-31, 21800 Tungsten Road, Cleveland 17, Ohio.

FORGE AND ROLL IT—Billets are available in Moly up to 12″ O.D. and 35″ long; in Tungsten up to 9″ O.D. and 29″ long. Slabs in Moly up to approximately 12″ width; in Tungsten up to approximately 9″ width. Minimum densities: Moly 95%, Tungsten 92%.

MACHINE IT—With proper techniques, G-E Molybdenum or Tungsten can be machined easily from billets, tubes and preforms. Density can be varied from 65-95%—±3% tolerance.



MELT IT—For vacuum arc melting, General Electric PS Moly consumable electrodes are available in diameters from 1″ to 12″; in PS Tungsten—1″ to 7″. Main features: high purity, density and straightness. Alloys of tungsten and molybdenum are available, too.

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GENERAL ELECTRIC

Circle 1261 on Page 48-S

Fatigue Failure . . .

proximating expected service as closely as possible. For fatigue lives of less than 10,000 cycles, however, there is evidence that the cyclic plastic-strain range (or the width of the hysteresis loop) provides better correlation with fatigue life than stress does.

A preliminary attempt to correlate the plastic-strain hysteresis energy with fatigue behavior has been made by measuring the microinelastic strains near the fatigue limit. Eight specimens of 4340 steel were tested in an axial fatigue machine.

An analytical relationship between stress amplitude and fatigue life was derived on the basis of four assumptions: *(a)* plastic-strain hysteresis energy is a measure of fatigue damage; *(b)* a logarithmic plot of true stress-true strain data is valid when extrapolated into the fatigue stress region; *(c)* the damaging energy per cycle for a given stress amplitude is constant, and equal to the area under a static stress-plastic strain curve; and *(d)* the total damaging energy for fatigue fracture is constant, and approximately equal to the area under the static true stress-true strain curve.

The limited number of tests indicates that plastic-strain hysteresis energy may provide a basis for predicting S-N curves with the static true stress-true strain curve providing sufficient information to predict fatigue life at stress amplitudes near and slightly above the fatigue limit.

The analysis expression predicts a longer life than observed in the high-stress region. This may be due to the rapid growth of the hysteresis loop. An adjustment could be made in the equation by incorporating the empirical hysteresis-loop growth-decay relationship.

In the low-stress region, the analytical expression does not predict a fatigue limit, but falls well below the experimental S-N curve. The slight decay of hysteresis energy at these stresses indicates that damaging plastic-strain hysteresis energy

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Circle 1264 on Page 48-B

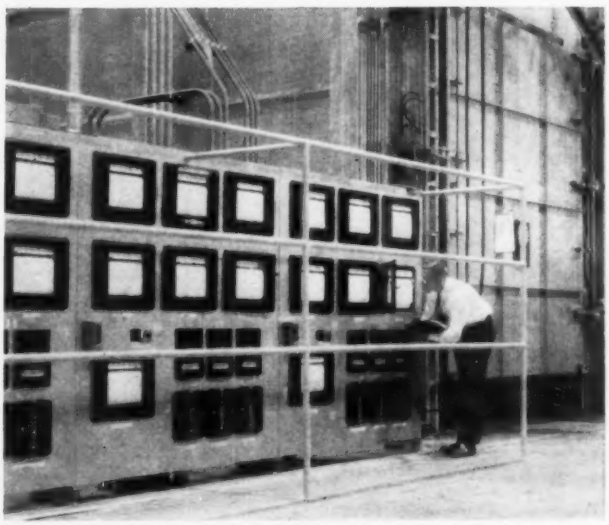
BRISTOL'S INSTRUMENTATION NEWS

News of instrumentation and automatic control in modern industry

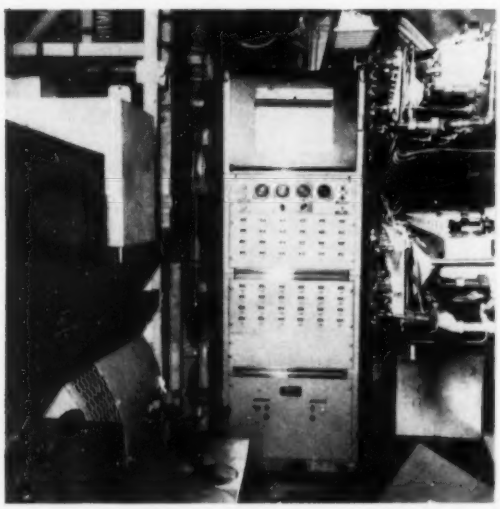
New multi-million dollar plant gets Bristol instrumentation

Bristol Electronic Dynamaster* Potentiometers play a vital part in the control set-up for the new fabricating plant of Anaconda Aluminum Company at Terre Haute, Indiana. They indicate, record, or automatically control temperatures in heat-treating, annealing, aging and soaking operations in a wide variety of furnaces throughout the plant. Other versatile Bristol Electronic Dynamaster instruments measure conveyor speed and function as multiple-zone safety-limit controls.

Comprising 11½ acres under one roof, the new plant turns out aluminum sheets, extrusions, tubes, ingots, and stamped shapes. Permanent records are a big plus in plant operation, says the furnace department foreman. "When a customer has a complaint or praise, we can always check the Bristol records. There's no guess-work involved anywhere."



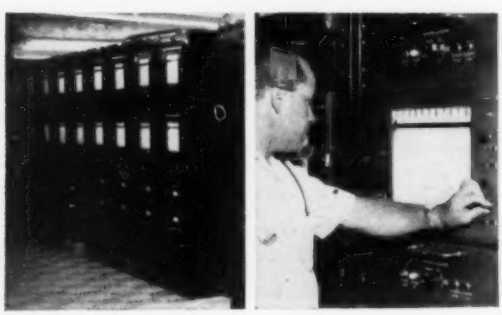
Bristol Electronic Dynamaster* Pyrometers shown here record and control an annealing furnace at Anaconda Aluminum Company's new, multi-million-dollar Terre Haute, Ind., plant. This is one of many panels featuring Bristol Dynamaster instruments in this ultra-modern new plant.



Bristol gets "deep dive diploma" on new Navy subs

The Navy's David Taylor Model Basin is using Gilmore Multichannel Strain Gage Plotters to assist in verifying the strength of new submarine hull designs. Gilmore Plotters, manufactured by Gilmore Industries, Cleveland, Ohio, are built around the basic Bristol Multi-point Dynamaster. Each new submarine design is tested by instrumenting the hull with strain gages and plotting strain vs load (depth). A plot is made at sea level and at 50-ft depth increments. A resultant straight-line plot for all stress points proves the design sound.

The USS ALBACORE was the first submarine tested with results plotted on these units. The ALBACORE embodies new design concepts which have contributed significantly to the spectacular performances of more recent atomic submarines. Most recent was USS SKIPJACK. This use of automatic strain-recording equipment saves manpower and time during the actual dive and in the subsequent analyses of the results.



Dynamaster* recorders monitor countdown variables in Titan missile blockhouse at Cape Canaveral

A large bank of Bristol Dynamaster recording instruments is prominent among the equipment supplied by The Martin Company's Cocoa Division for this blockhouse for the Titan ICBM at the Air Force Missile Test Center, Cape Canaveral. Dynamaster electronic instruments are also in other phases of the Titan ICBM program at Martin's Denver Division. Here they are used in the Propulsion Laboratory to check out kill parameters during tests, and also with the elevated temperature test equipment for aerodynamic flight simulation.

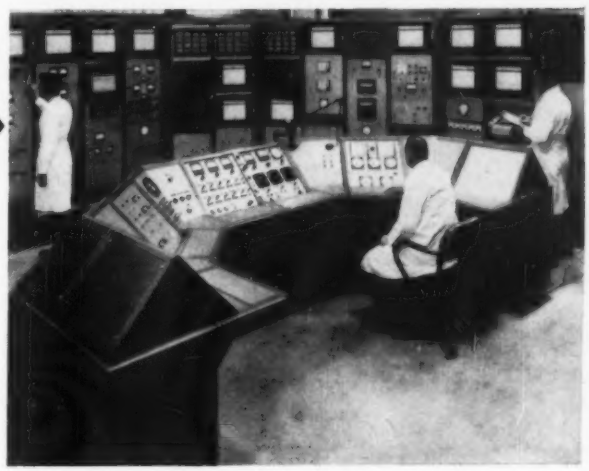
Electronic, nuclear ceramics development at Westinghouse aided by flexible temperature control panel

Bristol Round-Chart Program Controller, Double-Range Controller, Strip-Chart Recorder and Free-Vane Controller are tied into panel patchboard.

This instrument panel was designed by Westinghouse to give utmost versatility in furnace control at the Ceramic Materials Laboratory of Westinghouse Electric Corporation, Pittsburgh, Pa.

Furnaces controlled here are used in development of ceramic materials, such as nuclear fuels, thermistors, ferrites, ceramic resistors and other speciality ceramics. These range from low-temperature (only 1000°F) short cycles to high-temperature (up to 3000°F) cycles involving three soaks over a 72-hour period. Bristol instruments are playing an ever increasing role in modern basic and industrial research. Make sure you have full details before you purchase another instrument for lab use.

Dynamasters record vital data on new Army reactor



World's first mobile self-contained nuclear power plant and first U. S. gas-cooled reactor for generating power—these are the dual aims of the Gas-Cooled Reactor Experiment Program (GCRE-1), being carried out at the National Reactor Testing Station, Idaho, for the U. S. Army and U. S. Atomic Energy Commission by Aerojet-General Nucleonics.

Bristol Dynamaster Potentiometer and bridge instruments have been selected by Aerojet-General, prime contractors and builders of both the reactor and its control stations, to record vital reactor data.

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Circle 1265 on Page 48-B

Fatigue Failure . . .

dies out due to cyclic strain-hardening before the critical total plastic energy for fracture is attained.

The limited evidence offers some hope that use of static true stress-true strain data can reduce the number of tests required to establish fatigue lives. Future investigation is necessary to establish the validity of micro-plastic-strain hysteresis energy as a criterion for fatigue failure.

C. O. SMITH

Impregnating Steel With Titanium

Digest of "Surface Impregnation of Steel With Titanium in Molten Salts", by A. N. Minkevich and A. Gvozdev, *Izvestiya VUZ-Chernia Metallurgiya*, No. 2, February 1960, p. 151-156; Brutcher Translation No. 4842.

IN EXPERIMENTS CONDUCTED at the Moscow Steel Institute, the authors investigated the feasibility of titanizing surfaces in molten salt baths. Most of the research employed a steel containing 0.08% C, but a medium carbon steel was also used in a few experiments.

The researchers did their surface treating in a bath of molten sodium chloride containing 10 to 20% powdered TiO_x, a titanium-oxygen compound whch was prepared by melting titanium powder with titanium dioxide in an inert atmosphere. (Nominally the TiO_x alloy which resulted contained 10 at.% O_2.)

Titanizing experiments were run in a vertical electrically heated tube furnace. A Nichrome crucible, 2½ in. diameter by 6 in. long, contained the bath, and there were provisions for inserting and removing specimens and for maintaining a helium atmosphere in the furnace.

Specimens were treated from 1 to 8 hr. at 950 to 1100° C. (1750 to 2000° F.). The resulting surfaces exhibited a thin, hard outer zone up to 0.03 mm. thick, and a diffusion zone of coarse, columnar grain structure ranging up to 0.4 mm. in depth.

Microhardness, X-ray and analytical approaches, used to determine the nature of the metallized case, showed that the surface layer was $TiFe_2$ containing 30% Ti, a hexagonal structure. The diffusion zone was alpha iron with lattice expanded to accommodate the titanium atoms. Surface microhardness values ranged from 1000 to more than 2000 Knoop, giving rise to the conclusion that carbon diffusion into the case from the matrix iron served to produce some TiC. In fact, strong X-ray lines corresponding to TiC were observed in some specimens, particularly those which used medium carbon steels as experimental stock. Tests up to 120 hr. duration in 4% nitric acid indicated that titanized specimens had a high resistance to corrosion.

The authors concluded that titanizing of steel in molten salt baths takes place chiefly through direct contact between the surface of the steel and the fine powders of TiO_x suspended in the bath, in spite of the presence of lower valence titanium ions (Ti^{+3}) in the bath. This mechanism seems open to serious doubt.

J. L. WYATT

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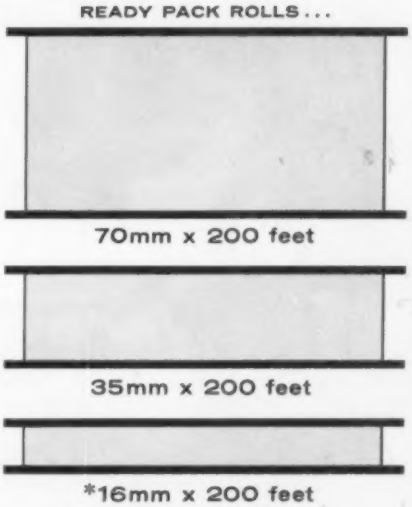

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Circle 1267 on Page 48-E

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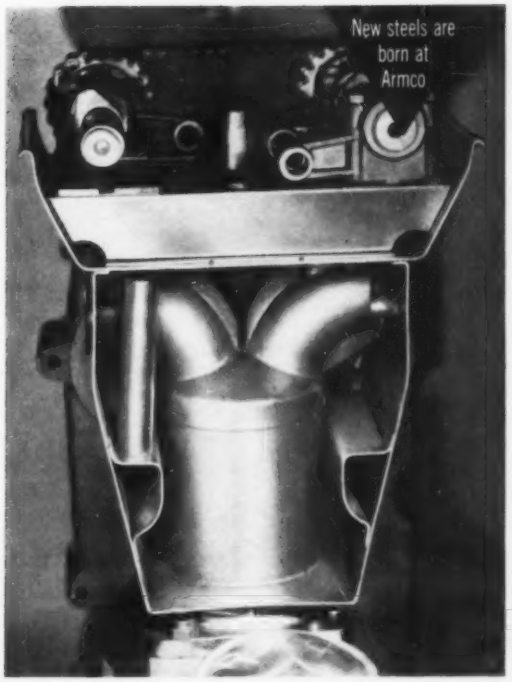

Cutaway shows stainless parts of the "TnT" Engine: Jacket, coolant galleries, valve pan, cylinders and heads, exhaust and intake ports, and spark plug tubes.

Concentrated power in a lightweight package. That's the new Tyce/Taylor "TnT" Engine produced by Tyce Engineering Corporation, Chula Vista, California. In its 135 cu. in. displacement, this compact power plant generates 175 h.p. It weighs only 175 pounds.

Most unique feature of this engine is a block assembly fabricated from Armco 18-8 Stainless Steel *sheets*. Thin gage components dissipate heat much faster, help hold down engine weight. Uniform wall thickness minimizes "hot spots" and pre-ignition; permits 14:1 compression ratio on regular gasoline. Heat resistance and corrosion resistance of Armco Stainless Steel also are important to the engine's durability.

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Circle 1268 on Page 48-8

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Leading off our March report on Producing for the New Technologies is "Metals and Fabrication Methods for the B-70" (p. 70). Written by Wayne A. Reinsch, this article reveals for the first time the details on types of metals and the precision techniques used in fabricating the B-70. Now supervisor of material and process engineering at the Los Angeles Div. of North American Aviation, Inc., Mr. Reinsch studied at Stanford University, receiving his B.S. degree in chemical engineering in 1946 and his M.S. in physical metallurgy a year later. He was employed on engineering structures materials for Chance-Vought Aircraft for five years, then in 1955 joined North American.

Active in several technical organizations, he is currently on the Los Angeles Chapter executive committee and program chairman for the 1961 Western Metal Congress.

His other interests, besides his family (Marjorie, his wife, and two sons, Steven 11 and Jack 16), are golf, fishing, hiking and oil painting.

Surface decarburization as a means for toughening sheet surfaces in missile cases is suggested by John M. Lynch in his article on p. 78. Since 1958, he has been a development engineer specializing in heat treating at Aerojet-General's solid rocket plant in Sacramento, Calif. He first worked in the applied studies department of the Polaris project designing fixtures and developing heat treating processes. More recently has been assigned to materials research and development, dealing with heat treating techniques and fixtures for solid-fuel rockets and missiles. In the photo, he is shown (on the right) with H. C. Olson who is in charge of the heat treat process at Aerojet.

A 1949 graduate of Fordham University with a B.S. degree in science,

he continued his studies at the R.C.A. Institute in New York and completed extension courses. (He also taught an extension course in electronics.) He was in the heat treat section of the material control laboratory of Pratt and Whitney Aircraft for 5½ years before joining Aerojet.

"Materials for Uncooled Rocket Nozzles" (p. 81) is based on work carried out by A. V. Levy while he was manager of materials and fabrication engineering, at the Aircraft Div. of Hughes Tool Co. in Culver City, Calif. Now with Aerojet-General Corp. in Sacramento, Calif., he heads the materials research and development department at the solid rocket

plant. He joined Hughes in 1959, after eight years as supervisor in the materials and processes section for Marquardt Corp. Before that, he studied at the University of California in Berkeley where he received his B.S. degree in engineering in 1950 and his M.S. in physical metallurgy a year later.

W. M. Boam is well-qualified to discuss the materials problems in design and fabrication of the liquid-fueled Titan ICBM – he is assistant department head of research and materials department at Aerojet-General's liquid rocket plant, in charge of projects covering the development and application of metals and nonmetallic material for liquid-fueled rocket engines. He received his degree in metallurgical engineering from the Montana School of Mines in 1942, and for 15 years worked in the aircraft engine field on material problems.

His others interests are not too surprisingly centered on his teen-age sons, Peter and Jeff – and now include bass fishing, photography and football. His wife Flora and four-year old Pam complete the family.

"Brazing Missile and Electronic Components in Dry Hydrogen" is the first part of a comprehensive report by Harry E. Lewis, president and general manager of Pyromet Co., in San Carlos, Calif., in which he covers the many factors to be considered for successful brazing in dry hydrogen. He has had over 30 years' experience in designing furnaces and setups for specialized brazing and heat treating applications, in studying metallurgical characteristics of brazed joints and in developing the use of controlled atmospheres – including a long tenure with General Electric.

● ● ●

L. A. Hauser and M. C. Metzger, two metallurgical engineers in the technical service department of Universal-Cyclops Steel Corp., offer suggestions on how to solve some of the problems of machining space-age metals on p. 97. Mr. Hauser (shown below, right, with Mr. Metzger) has been with Universal-Cyclops for over ten years, first as superintendent of the metallurgical laboratory and since 1956 as metallurgical engineer, specializing in toolsteels. He received his B.S. (1940) and M.S. (1949) degrees in metallurgical engineering from the University of Pittsburgh.

Although fishing has been his lifetime hobby, he has acquired a liking for golf in the past few years and that sport now takes up much of his time.

Mr. Metzger, who joined Universal-Cyclops as a mill metallurgist in 1952, specializes in the superalloys. He graduated from Fenn College in Cleveland with a B.S. degree in metallurgical engineering, and then worked 12 years for Thompson-Ramo-Wooldridge, Inc., as a metallurgist and chief engineer in the Metpro Div., where he was mainly concerned with high-temperature metal applications.

He's on the roster of several technical groups and is on committees for A.S.M., A.S.T.M., A.I.S.I. and S.A.E. His off-hours are spent with his family – he helps his two sons with their stamp and coin collections – and in active exercise – golfing and swimming.

● ● ●

"Materials and Fabrication Methods for the Bomarc" (p. 107) was written by R. H. Nelson in conjunction with several engineers from Boeing Airplane Co. in Seattle, Wash. Now manufacturing manager of the Bomarc program, he received his B.S. in aeronautical engineering from the University of Minnesota and since 1934 has been with Boeing, working on all phases of aircraft design and, during the Second World War, as project engineer in charge of all B-17 engineering. Entering the missile field in 1946, he was assigned as project engineer for the GAPA program, directing the design development and testing of more than 100 missiles on this project. He took part in the conception of the Bomarc weapon system and was assigned as project engineer in 1950. He took his present post three years later, and is now responsible for the development of the Boeing team manufacturing IM-99 experimental and production missiles.

The author of "Brazing Ceramics to Metals" (p. 126), Leon Lerman, has specialized in the ceramics field since receiving his degree in ceramic engineering from New York State College of Ceramics in 1939. He joined Sylvania Electric Products Co. in 1957 and is head of the chemistry, metallurgy and ceramics branch of the microwave components laboratory at Mountain View, Calif. He has also taught ceramic technology at San Jose State College.

His favorite pastime is bridge, though picnicking rates a close second. With his wife, son and daughter (when she is home on vacation from Mills College), he enjoys outings on the Monterey Peninsula.

David K. Davies, author of "Design and Manufacture of Reactor Vessels" (p. 101), has more than 12 years' experience with atomic energy components at Babcock & Wilcox Co.'s Boiler Div. in Barberton, Ohio.

A graduate of Lehigh University (in 1948), he began his career with B&W as a design engineer, primarily concerned with the stress analysis and design of high-pressure, high-temperature vessels for process equip-

ment and nuclear reactors. His work has involved submarine reactors, materials testing reactors, as well as other steam-generating equipment utilizing nuclear fuels.

Mr. Davies, now section manager of nuclear components propositions, admits that golf is his favorite hobby – when his four children, Catherine, Thomas, Ruth and Megan, can spare him the time.

John V. Long, director of research for Solar Aircraft Co. discusses "Refractory Coatings for High-Temperature Protection" on p. 114.

A graduate in physics from the University of California at Los Angeles, he has directed the work at Solar's research laboratories since 1951, and currently is involved in developing better joining methods for new alloys and materials, and working on heat and corrosion resistant protective coatings and on high-strength structures for industrial and aerospace use.

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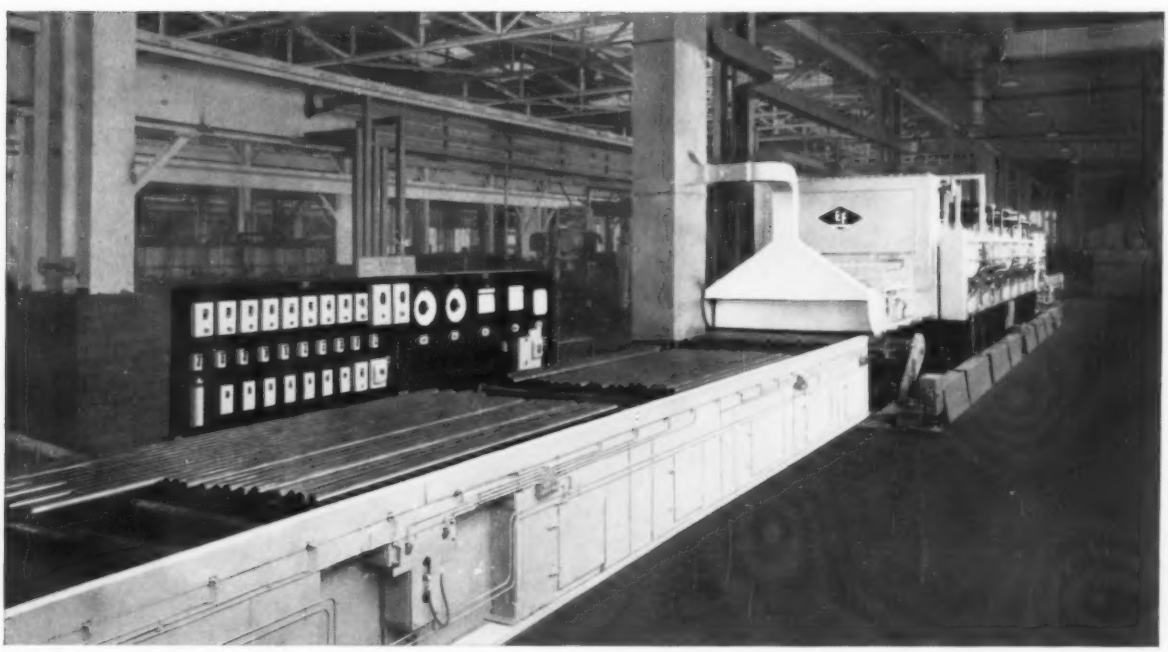

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Circle 1139 on Page 48-B

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